54812

RI/FS

U.S. v. AVX ...
Litigation D...

WORK PLAN

for

MODELING OF THE TRANSPORT, DISTRIBUTION, AND FATE OF PCBs AND HEAVY METALS IN THE ACUSHNET RIVER/ NEW BEDFORD HARBOR/BUZZARDS BAY SYSTEM

Under Soliciation No. Z0831101

to

NUS CORPORATION
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

May 18, 1984

from

BATTELLE
New England Marine Research Laboratory
397 Washington Street
Duxbury, MA 02332

TABLE OF CONTENTS

Page

1. INTRODUCTION 1

2. OBJECTIVE AND SCOPE OF PROJECT 4

 2.1 Objectives 4

 2.2 Scope 4

 2.3 Background Information 7

  2.3.1 Metcalf & Eddy Database 7
  2.3.2 Recent Studies 17
  2.3.3 Hydrographic Background 17
  2.3.4 Physical/Chemical Properties of PCBs and Metals 19
  2.3.5 Local Marine Biota 22
  2.3.6 Biological and Bioenergetic Database for Species of Concern 23
  2.3.7 PCBs and Copper Bioaccumulation Database for Food-Chain Species 24

 2.4 Data Usage 25

3. PROJECT DESCRIPTION 26

 3.1 Hydrodynamics 26

 3.2 Field Sampling Program 26

  3.2.1 Field Sampling Plan 26
  3.2.2 Sediment and Water Column Sampling 38

   3.2.2.1 Sediments 38
   3.2.2.2 Water Column Sampling 42
   3.2.2.3 Biological Sampling 42

  3.2.3 Shipboard Processing of Samples 45

   3.2.3.1 Sediments 45
   3.2.3.2 Water Column Samples 46

TABLE OF CONTENTS
(Continued)

		Page
3.3	Laboratory K_d Determinations and Particle Size Fraction Verification	47
	3.3.1 Objectives	47
	3.3.2 Desorption Experiments	48
	3.3.3 Sorption Experiments	49
	3.3.4 SPM Size Fraction Verifications	51
3.4	Laboratory Bioaccumulation Studies	53
	3.4.1 Assimilation Efficiency of Ingested PCBs and Copper	53
	3.4.2 Bioconcentration Factor and Excretion Rate	55
3.5	Laboratory Analytical Chemistry Program	56
	3.5.1 Methodology - General	56
	3.5.2 Methodology - Technical Requirements	65
	3.5.3 Immediate Laboratory Processing	69
	3.5.4 Quality Control/Quality Assurance	75
	3.5.5 Incorporation of the Analytical Program Into the Overall Study	76
	3.5.6 Turn-Around Time	77
3.6.	Hydrodynamic and Sediment/Contaminant Transport Modeling	79
	3.6.1 Introduction	79
	3.6.2 Overview of Modeling Task	81
	3.6.2.1 Review and Evaluation of Existing Data	83
	3.6.2.2 Modification of the Model	83
	3.6.2.3 Field Sampling Support and Data Analysis	83
	3.6.2.4 Application of the Model	83
	3.6.2.5 Evaluation and Reporting	83
	3.6.3 Detailed Description of Subtasks	84
	3.6.3.1 Review and Analysis of Existing Data	84
	3.6.3.2 Modeling Modifications	86
	3.6.3.3 Field Sampling Support and Data Analysis	89
	3.6.3.4 Application of the Model	90
	3.6.3.5 Evaluation and Reporting	95
	Appendix A - Hydrodynamic and Contaminant Transport Computer Code Selection	97

TABLE OF CONTENTS
(Continued)

		Page
3.7	Biological Food Web Modeling	104
	3.7.1 Task 1 - Evaluation of Existing Data	106
	3.7.2 Task 2 - Application of Biological Food Web Model	107
	3.7.3 Task 3 - Preliminary Calibration of the Food Web Model	113
	3.7.4 Task 4 - Evaluation of the 1984-85 Field and Laboratory Data and Detailed Calibration of the Food Web Model	114
	3.7.5 Task 5 - Evaluation of Effectiveness of Remedial Action	116
	3.7.6 Task 6 - Reporting and Documentation of Analysis	120
3.8	Data Management	120
	3.8.1 Description of Existing Database	120
	3.8.2 Information System Design	121
	3.8.3 Data Management Operations	124
3.9	Reports	125
	3.9.1 Final Report	125
	3.9.2 Interim Reports	126
3.10	Proposal Submitted to Battelle Laboratories by Woods Hole Oceanographic Institution	127
	Letter of Commitment, Dr. W.D. Grant, W.H.O.I.	146
4.	MANAGEMENT	153
4.1	Management Team	153
4.2	Management System and Management Controls	153
	4.2.1 Work Breakdown Structure	154
	4.2.2 Line of Balance	154
	4.2.3 Manpower Loading	161
	4.2.4 Resolution of Conflicts and Problems	161
	4.2.5 Cost Control	162
4.3	Field Sampling QC	166
	4.3.1 Field Sampling Protocol	166
	4.3.2 Field Log Book	166
	4.3.3 Chain-of-Custody Record	167

TABLE OF CONTENTS
(Continued)

		Page
4.3.4	Field Sampling Verification - Shipboard Contaminants	168
4.3.4.1	Shipboard Contaminants	168
4.3.4.2	Field Sampling Verification - Duplicate Samples	168
4.3.4.3	Field Sampling Verification - Split Samples	168
4.3.4.4	Field Sampling Verification - Spiked Samples	168
5.	TIME AND COSTS	170
6.	LITERATURE CITED	172

LIST OF TABLES

Table 2.3.1.	Concentrations of PCBs in Treated Wastewater at the Clark's Point Treatment Plant	10
Table 2.3.2.	Summary of Some Important Hydrographic Parameters From the Acushnet River/New Bedford Harbor/ Buzzards Bay System	21
Table 3.2.1.	Sampling Schedule	35
Table 3.2.2.	Sediment Sampling for Trace Metal and PCB Analysis Second Boundary Conditions; Storm Event Conditions, November-December, 1984	39
Table 3.2.3.	Sediment Sampling for Trace Metal and PCB Analysis Initial Conditions, September, 1984	40
Table 3.2.4.	Sediment Sampling for Trace Metal and PCB Analysis, Biological Sampling Trips, July 1984, April 1985	41
Table 3.2.5.	Water Sampling, Immediate Shipboard Processing	43
Table 3.2.6.	Biota Samples and Collection Methods for the Food-Chain Model	44
Table 3.3.1.	Desorption Study Sample Summary (for PCB and Cu)	50
Table 3.3.2.	Sorption Study Sample Summary (PCB and Cu)	52
Table 3.3.3.	Summary of Sample Requirements for Desorption, Sorption Via Verification Studies (PCB and Cu)	54
Table 3.4.1.	Summary of Number of Samples for Chemical Analysis Generated in the K_d and Bioaccumulation Studies	57

TABLE OF CONTENTS
(Continued)

Page

LIST OF TABLES
(Continued)

Table 3.5.1.	Estimate of the Degree of Sorption of PCB Isomers Onto Colloidal Organic Matter of Concentrations 1.0 and 10 mg Org C/l Using Empirical Equations from Means et al. (1980)	60
Table 3.5.2.	Laboratory Analytical Methods	66
Table 3.5.3.	Laboratory Analytical Limits of Detection and Reporting Units	67
Table 3.5.4.	Immediate Laboratory Processing of Field Samples	70
Table 3.5.5.	Analytical Chemistry - Turn-Around Time (Minimum Requirements)	78
Table 3.6.1.	Summary of Radionuclide-Transport Models	101
Table 3.6.2.	Selected Chemical Fate Models for Surface Water Systems	102
Table 4.2.1.	Description of Key Activities in the New Bedford Harbor Modeling Program as Shown Graphically in The Accompanying Pert Chart (Figure 4.3.1)	157
Table 4.3.1.	Shipboard Contaminants	169
Table 5.1.	Cost Breakdown (Including Fee) by Task and Subtask	171

LIST OF FIGURES

Figure 2.3.1.	PCBs in Water (ppb)	9
Figure 2.3.2.	PCBs in Hard-Shell Clams (Mercenaria mercenaria) (ppm)	11
Figure 2.3.3.	PCBs in Lobsters (Homarus americanus) (ppm wet wt.)	13
Figure 2.3.4.	PCBs in Winter Flounder (Pseudopleuronectes americanus) (ppm wet wt.)	14
Figure 2.3.5.	Capillary GC/ECD Trace (A) and Isomeric Composition (B) of Typical Buzzards Bay Sediment Sample	15
Figure 2.3.6.	PCB Iosmeric Distributions for Clams (Pitar) and Lobsters (Homarus americanus)	16

TABLE OF CONTENTS
(Continued)

Page

LIST OF FIGURES
(Continued)

Figure 2.3.7.	Postulated Circulation and Mixing in Buzzards Bay	20
Figure 3.2.1.	Sediment Sampling Stations, June-July, 1984	27
Figure 3.2.2.	Sediment Sampling Stations, June-July, 1984	28
Figure 3.2.3.	Sediment Sampling Stations June-July, 1984	29
Figure 3.2.4.	Sediment Sampling Stations June-July, 1984	30
Figure 3.2.5.	Sediment Sampling Stations, June-July, 1984	31
Figure 3.2.6.	Water Sampling and Seasonal Sampling Stations, 1984	32
Figure 3.2.7.	Water Sampling and Seasonal Sampling Stations, 1984	33
Figure 3.2.8.	Biota Sampling Areas and Corresponding Sediment and Water Column Sampling Stations	34
Figure 3.5.1.	Capillary GC Trace of Mixed Aroclor (1016, 1242, 1254, 1248) Standard	59
Figure 3.5.2.	Capillary GC/ECD Trace (A) and Isomeric Composition (B) of Typical Buzzards Bay Sediment Sample	61
Figure 3.5.3.	PCB Isomeric Distributions for Clams (Pitar) and Lobsters (Homarus americanus)	62
Figure 3.5.4.	PCB Compositional Plots - Arctica islandica; Stations 242, 241 From Buzzards Bay, Other Stations From New York Bight Area	63
Figure 3.5.5.	PCB Compositional Plots of Some Common Aroclor Formulations	64
Figure 3.5.6.	Immediate Laboratory Processing of Sediment Samples, Depth Profile	71
Figure 3.5.7.	Immediate Processing of Water Samples, Copper Analysis	72
Figure 3.5.8.	Immediate Laboratory Processing of Sediment Samples, Surface Sediment, Chemical Characterization of Gross Sediment	73

TABLE OF CONTENTS
(Continued)

Page

LIST OF FIGURES
(Continued)

Figure 3.5.9.	Immediate Laboratory Processing of Sediment Samples, Surface Sediment Compartment Differentiation	74
Figure 3.6.1.	Organization of the Physical/Chemical Modeling Task	82
Figure 3.7.1.	PCB Concentration Factors From Laboratory Experiments and Field Observations	105
Figure 3.7.2.	Schematic of Major Features in PCB Distribution Throughout Food Chain	108
Figure 3.7.3.	Schematic of Compartments in Food Web Model and Striped Bass (Morone saxatilis) Model	110
Figure 3.7.4.	Lobster (Homarus americanus) Food Chain	111
Figure 3.7.5.	Winter Flounder (Pseudopleuronectes americanus) Food Chain	112
Figure 3.7.6.	Components of PCB Concentration in Striped Bass (Morone saxatilis)	115
Figure 3.7.7.	Food Web Model Projection, Small Fish	118
Figure 3.7.8.	Projected Response of Different Age Striped Bass to A Five-Fold Decrease in the Estuary PCB Water and Food Concentrations	119
Figure 3.8.1.	Schematic Hardware Configuration of Battelle Information Management System	123
Figure 4.2.1.	Work Breakdown Structure for the New Bedford Harbor PCB Modeling Project	155
Figure 4.2.2.	Pert Chart for the New Bedford Harbor PCB Modeling Program	156
Figure 4.2.3.	Sample Monthly Cost Summary Sheet for Each Work Item	163
Figure 4.2.4.	PMS Status Report Example	164
Figure 4.2.5.	Graphic Performance Report Example	165

RI/FS
WORK PLAN

for

MODELING OF THE TRANSPORT, DISTRIBUTION, AND FATE OF PCBs AND HEAVY METALS IN THE ACUSHNET RIVER/ NEW BEDFORD HARBOR/BUZZARDS BAY SYSTEM

Under Solicitation No. Z0831101

to

NUS CORPORATION
Park West Two
Cliff Mine Road
Pittsburgh, PA 15275

from

BATTELLE
New England Marine Research Laboratory
397 Washington Street
Duxbury, MA 02332

May 18, 1984

1. INTRODUCTION

The Acushnet River estuary, which in its middle and lower reaches forms New Bedford Harbor, Massachusetts, is heavily contaminated with polychlorinated biphenyls (PCBs) and several heavy metals. The cities of New Bedford and Fairhaven, with a combined population in excess of 100,000 occupy the west and east banks of the estuary, respectively.

New Bedford has been a major East Coast shipping and fishing port since colonial times. Although commercial fishing continues to be an important local industry, light manufacturing and processing industries sprang up in the area following the decline of the whaling industry in the mid-1800s. Current and past local industries include textiles, dying, electroplating, metal finishing, and electric component manufacture.

Two electric components-manufacturers, Cornell-Dubilier Electronics, Inc. and Aerovox Corp., have used PCBs in the manufacture of electrical capacitors since the 1940s. Waste water contaminated with PCBs was discharged by these and possibly other industries to the harbor and the municipal sewage system for at least thirty years. In addition, metals industries have discharged large volumes of metal-contaminated waste water to the harbor and sewage system for at least as long or perhaps much longer.

Until 1971, the capacitor manufacturers used primarily Aroclor 1242 and lesser amounts of Aroclor 1252 and 1254. In 1971, Monsanto replaced the more highly chlorinated mixtures with Aroclor 1016 which contained less heavily chlorinated biphenyls and was considered less environmentally damaging. Aroclor manufacture in the U.S. was banned altogether in 1976, but users were allowed to use up the Aroclor in stock. Cornell-Dubilier and Aerovox probably continued to use Aroclors in New Bedford until 1977 or 1978.

Elevated concentrations of PCBs, usually measured as Aroclor 1254, were first reported in sediments of New Bedford Harbor in 1975. Since then, a large number of investigations have documented the widespread contamination of sediments and marine biota of the Acushnet River, New Bedford Harbor and adjacent Buzzards Bay with PCBs. PCB concentrations in sediments of the upper Acushnet estuary, near the site of Aerovox, frequently exceed 500 mg/kg dry weight (ppm) and occasional samples contain in excess of 10,000-100,000 ppm (1-10 percent). Of the local estuarine biota, eels (Anguilla rostrata) appear to be the most heavily contaminated with body burdens occasionally in excess of 500 ppm. The FDA action level for edible portion of fish and shellfish is 5 ppm. Lobsters (Homarus americanus) also appear to be heavily contaminated, with concentrations in muscle tissue occasionally exceeding 50 ppm.

Because of the high level of PCB contamination of some commercially important fin- and shellfish, the Massachusetts Department of Public Health (DPH) issued a warning in March, 1977 that demersal finfish from the New Bedford Harbor area should not be consumed. In June, 1977, a second warning was issued relative to consumption of lobsters from the area. The New Bedford Harbor area was formally closed to fishing for human consumption on September 25, 1979. The closed area was divided into three sections, corresponding to biota sampling areas 1-3 in the present program (Figure 3.2.8). Area 1 is closed to the taking of all finfish, shellfish, and lobsters; Area 2 is closed to the taking of demersal finfish (i.e. eels, scup, flounder, and tautog) and lobsters; and Area 3 is closed to the taking of lobsters. In 1980, the Massachusetts Department of Environmental Quality Engineering designated the New Bedford Harbor PCB problem as a priority in the 1980 State-EPA agreement. In 1982, the Acushnet River estuary, New Bedford Harbor and adjacent Buzzards Bay were designated a U.S. Superfund hazardous waste site, and remedial action planning was initiated. More recently, the U.S. Justice Department filed a law suite on behalf of NOAA against the capacitor manufacturers seeking damages for the loss of natural resources in the region because of PCB contamination of fishery products and habitat.

Much less attention has been paid to the heavy metals problem. In 1977, sediments from the harbor were reported to contain substantially elevated concentrations of several heavy metals, including arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc. The most abundant metals were copper, chromium, and zinc. Some sediment samples contained in excess of one percent of these three metals combined.

New Bedford Harbor is a very busy port. It is utilized by a commercial fishing fleet of approximately 250-300 vessels and a recreational fleet of 300-400 small boats. Coast Guard cutters up to 315 feet long, cargo ships up to 585 feet long, and cruise ships up to 600 feet long regularly call at the port. Therefore, any remedial action must include consideration of the multiple uses of the affected area and proposals to improve and expand the boat-ship harbor. Various dredging operations seem like the most feasible remedial actions.

2. OBJECTIVE AND SCOPE OF PROJECT

2.1 OBJECTIVES

The overall objective of the sampling and modeling program is to develop, validate, calibrate, and apply mathematical models which will:

1. predict the movements, distribution and fate of PCBs and heavy metals in the Acushnet River, New Bedford Harbor, and adjacent Buzzards Bay;

2. predict the bioaccumulation, transfer, and possible biomagnification of PCBs and metals within key biological components of the local marine food chain, including lobsters, clams, and winter flounder;

3. assess the potential effects of dredging, other remedial actions, or storm events on the physical movements and food-chain transfer of PCBs and metals in the harbor and adjacent bay;

4. determine possible waste sources of PCBs and metals in different regions and biological components of the Acushnet River/New Bedford Harbor/Buzzards Bay system.

2.2 SCOPE

The work contained in this Work Plan can be divided into seven specific tasks.

1. Hydrodynamic field studies will be performed to determine the normal and storm-induced patterns of water currents in Buzzards Bay and the inner and outer New Bedford Harbor. An array of current meters will be deployed at the entrance to Buzzards Bay for approximately five months. This will establish conditions of water, sediment, and contaminant flux across the boundary of the physical/chemical model. Additional shorter-term current meter and drogue studies will be performed in the vicinity of New Bedford Harbor to establish patterns of current flow in this region during summer and winter conditions.

2. A field sampling program will be undertaken to provide chemical data for input to the physical/chemical, and food-chain models. Sampling will take place during

four seasons in 1984 and 1985 at up to 25 stations in the Acushnet River, New Bedford Harbor, and Buzzards Bay. Samples will include surficial sediment, surface and bottom water (collected in some cases at intervals during the tidal cycle), and marine animals. Selected vertical cores of sediment will be collected from New Bedford Harbor.

3. Two types of laboratory studies will be performed to provide site-specific information directly applicable to and required for the physical/chemical and food-chain models. Adsorption/desorption kinetics and constants for PCBs and metals and site sediments will be determined. The Kd's and other physical parameters determined empirically will be more accurate (relative to local conditions) than literature values and will better reflect the unique contamination situation of the harbor sediments.

Laboratory studies also will be performed to determine bioaccumulation factors, uptake efficiency from the gut (from food), and rates of release of different PCB components and metals by the food-chain animals of conern, namely lobster, flounder, and clam.

4. Although analytical chemistry is an integral and critical component of the overall sampling and modeling project, it is not covered in this Work Plan, since it is under the perview of the EPA Contract Laboratory Program. However, a brief description of the requirements for the chemical program is included.

Four PCB pseudocomponents (representing different degrees of chlorination and different physical/chemical properties) and one metal (copper) will be measured in all samples. In addition, most samples will be separated into two or more fractions. Sediments will be separated into sand, silt, clay, and pore water fractions for analysis. Water samples will be separated into particulate and soluble fractions. In most cases, edible portion of biota samples (muscle) will be dissected out for analysis after the animal is measured and weighed. These separations are necessary because the contaminants in the different fractions behave differently, both physically and biologically, and the models are designed to consider and predict these different behaviors. The fractionations must be performed immediately, either on board the sampling boat or immediately after return to the laboratory. Because of the low concentrations of contaminants expected in solution near the model boundary at the entrance to Buzzards Bay, large volume (20 liter) water samples will be collected by pumping and will be extracted immediately. Sediment, water, particulate, and biota samples from the laboratory experiments also will have to be handled and processed in a similar fashion. The validity of the predictions and assessments produced by the models is highly dependent on the quality of the chemical analyses. The analytical chemistry task is on the critical path of the whole project. Therefore, the large number of analyses required in this project must be performed rapidly or the whole project will experience serious delays. Therefore, the quality and effectiveness of the whole modeling project requires rapid generation of accurate analytical results.

5. The physical/chemical transport and fate of PCBs and metals in the New Bedford Harbor/Buzzards Bay system will be modeled by a time-varying three-dimensional model, TEMPEST/FLESCOT, developed by Battelle. The model will be used to predict: the distribution of flow affected by such factors as tide and wind; distribution of water temperature and salinity; distribution of three size classes/types of sediments; distribution of dissolved contaminants; distributions of particulate contaminants sorbed to three size classes/types of suspended sediments; distribution of contaminants in the bed sediments. Several minor modifications will be made to the model to adapt it to site-specific physical and hydrographic conditions.

6. An age/size-dependent food-chain model that considers bioenergetics of different species in the food chain and exposure to PCBs and metals via the water column and food will be used to predict the movements of contaminants through key components of the New Bedford Harbor/Buzzards Bay food chain and impacts of various remedial actions on long-term food-chain contamination. The species being used as representatives of the local food chain include the commercial species, lobsters (Homarus americanus), winter flounder (Pseudopleuronectes americanus) and hard shell clam (Mercenaria mercenaria). Model prey organisms include rock crabs (Cancer irroratus) or spider crabs (Libinia emarginata), mussels (Mytilus edulis) and benthic macroinfauna (polychaete worms). Three size classes of each species will be analyzed to account for age/size related differences in contaminant bioaccumulation and retention.

7. A computerized data management system will be utilized to store, access, and manipulate all data generated in this project plus germaine site-specific and generic data already in existance. This data file will be available to the sponsor at the end of the program. In addition, a formal final report documenting, summarizing, and synthesizing

the results of this project will be produced at the end of the project. Interim status/financial reports will be prepared and submitted to the sponsor at approximately quarterly intervals. Meetings of participants in the project, the sponsor (EPA and NUS) and the NOAA modeling task force will be held periodically during the project.

2.3 BACKGROUND INFORMATION

2.3.1 Metcalf & Eddy Database

Under contract to EPA, Region I, Metcalf and Eddy, Inc. has compiled and maintains a database of information about PCBs in the Acushnet River/New Bedford Harbor/Buzzards Bay system. The database contains more than 5,000 entries of PCB and metals concentrations in water, sediments, biota waste water and air from the estuarine system. The data were compiled from results of 23 analytical laboratories and 21 different municipal, state, federal, and private agencies and organizations. A total of 158 data references were used to compile the database.

At the outset of the current problem analysis, work plan development task, Battelle requested and received from Metcalf and Eddy a subset of these data from the 90 percent of the total entries that Metcalf and Eddy determined in their quality assurance review to be of sufficient quality and reliability for use. This subset of the total database includes 2,690 records for harbor sediments, 159 records of water column data, 35 records of treatment plant effluent, and 1,180 records of aquatic biota.

The Acushnet Estuary PCBs Data Management Final Report (Metcalf and Eddy, 1983) contains 18 contour and station maps summarizing the distribution of different Aroclors and total PCBs in surficial and subsurface sediments of the Acushnet River and New Bedford Harbor. Highest PCB concentrations are in sediments from the upper part of the estuary, north of the Coggeshall Street bridge adjacent to the Aerovox site. Sediments containing more than 10,000 ppm PCBs have been reported from isolated locations in this area. PCB concentrations in the 50-100 ppm range have been reported in sediments from several locations in the inner harbor between the hurricane barrier and the Coggeshall Street bridge, and in the outer harbor adjacent to the Cornell-Dubilier site and the outfall of the New Bedford sewage treatment plant at Clark's Point. Well over half the data entries obtained from Metcalf and Eddy for sediment PCB concentrations show non-detectable (zero) values, probably reflecting inappropriate sample size, sample processing or analytical method more often than low environmental concentration. However, the sediment data are useful to the modeling effort because they provide an overall picture of the distribution of PCBs in sediments of the estuary system.

There are many fewer entries in the data file for PCB concentrations in the water column. In this case, more than 90 percent of the entires report non-detectible levels. The remaining data are summarized in Figure 2.3.1. In only a few cases have dissolved and particulate PCB concentrations been measured separately. The limited available data indicate a trend toward decreasing PCB concentrations in the water as one moves from the upper Acushnet estuary, through the inner harbor and into the outer harbor and Buzzards Bay.

The capacitor manufacturers apparently discharged substantial amounts of PCB-contaminated wastewater to the New Bedford sewerage system. As a result, the treated waste water discharged from the sewage treatment plant at Clark's Point to lower New Bedford Harbor, as well as the combined wastewater-storm sewer overflows, are contaminated with PCBs. The available data for the treated effluent, arranged by date, are summarized in Table 2.3.1. Probably in part because of the different analytical methods used and PCB mixtures sought, there is no clear temporal trend toward increasing or decreasing PCB concentrations in the effluent. The most recent values, obtained just over two years ago, indicate a continued significant level of PCB contamination of the effluent. Similar ocncentrations have been reported in the combined sewage overflows, and solid samples from the sewage lines contain up to 78,000 ppm PCB (Hunt et. al., 1983).

There is a fairly extensive database on PCB concentrations in biota of the Acushnet River-Buzzards Bay system. Some species have been analyzed more frequently than others. There is a fairly large number of site-specific PCB analyses of the three species of marine animals which will form the focus of our food-chain modeling. Hard-shell clams (Mercenaria mercenaria) are extremely abundant in shallow waters throughout the study area and they have been analyzed frequently. Data from the Metcalf and Eddy data file plus recent (January, 1983) data from GCA Corp. (DeLorenzo, 1983) are summarized in Figure 3.2.2. There is a definite trend for PCB concentrations in clams to decrease as one moves from the inner harbor to the outer harbor to Buzzards Bay. There are no data from locations north of the Coggeshall Street bridge because there is very little living benthic macrofauna in this area. Additional "hot spots" occur outside the hurricane barrier at Clark's Point near the sewage outfall and opposite Cornell-Dubilier.

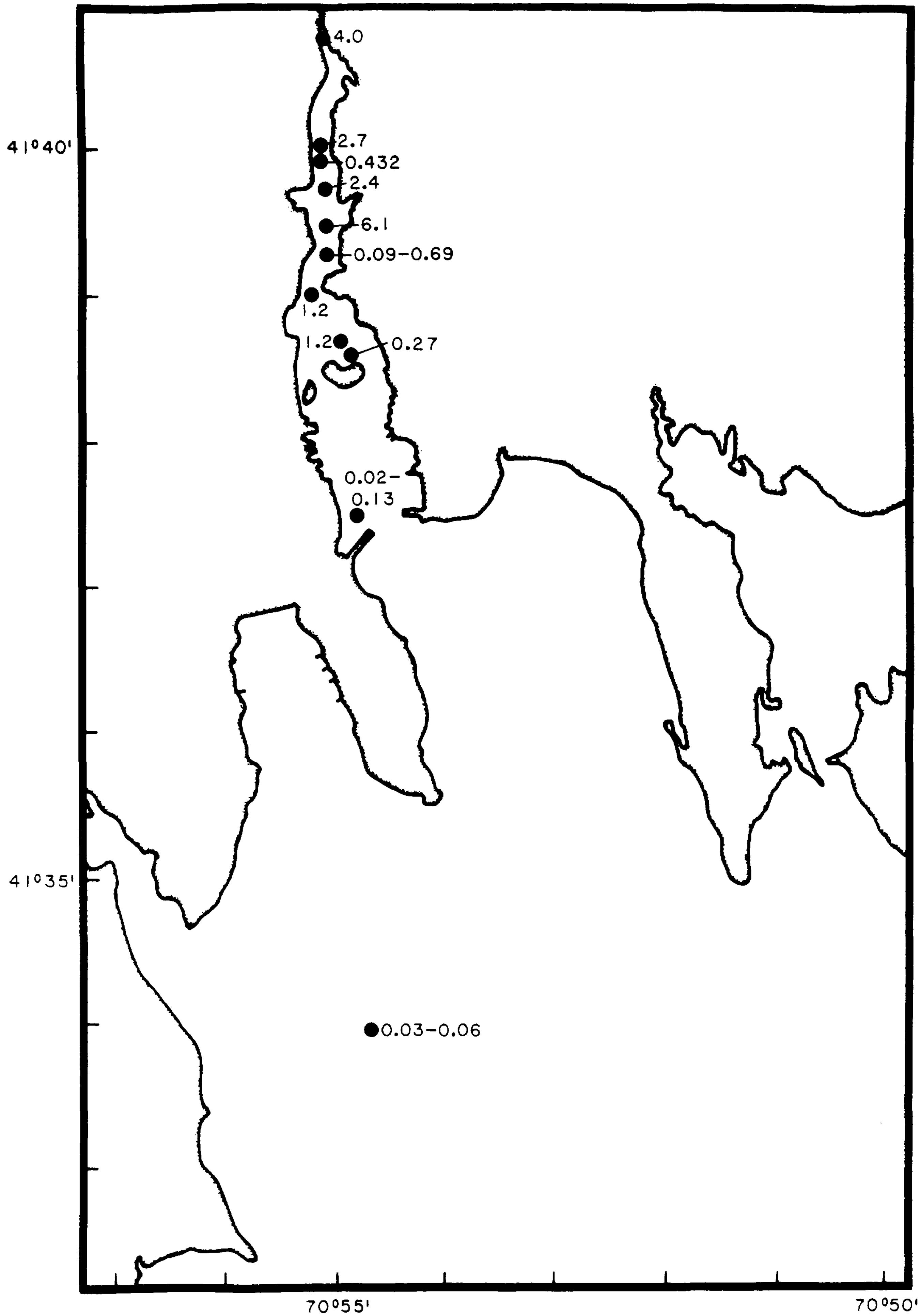


FIGURE 2.3.1. PCBs IN WATER (ppb).

TABLE 2.3.1. CONCENTRATIONS OF PCBs IN TREATED WASTEWATER AT THE CLARK'S POINT TREATMENT PLANT

Date	PCB Type[1]	Concentration (ppb)[2]
07/19/76	Total	119
02/09/77	NS	3.5
03/01/77	NS	2.5-8.25(4)
03/03/77	NS	2.75-5.75(2)
03/09/77	NS	3.0
03/27/80	1016	0.13
03/27/80	1254	*
02/23/81	1016	8.16
02/23/81	1254	*
02/24/81	1016	1.43
02/24/81	1254	*
02/25/81	1016	*
02/25/81	1254	*
02/26/81	1016	*
02/26/81	1254	*
03/02/81	1016	*
03/02/81	1254	*
03/03/81	1016	*
03/03/81	1254	*
03/04/81	1016	*
03/04/81	1254	*
03/05/81	1016	*
03/05/81	1254	*
06/15/81	1242	33.0
03/10/82	Total	1.8-3.2
03/15/82	Total	4.3-5.7
03/20/82	Total	3.8-3.9

[1]NS, not specified; 1016, Aroclor 1016; 1254, Aroclor 1254; 1242, Aroclor 1242; Total, Total PCBs.

[2]*, Not detected by method used.

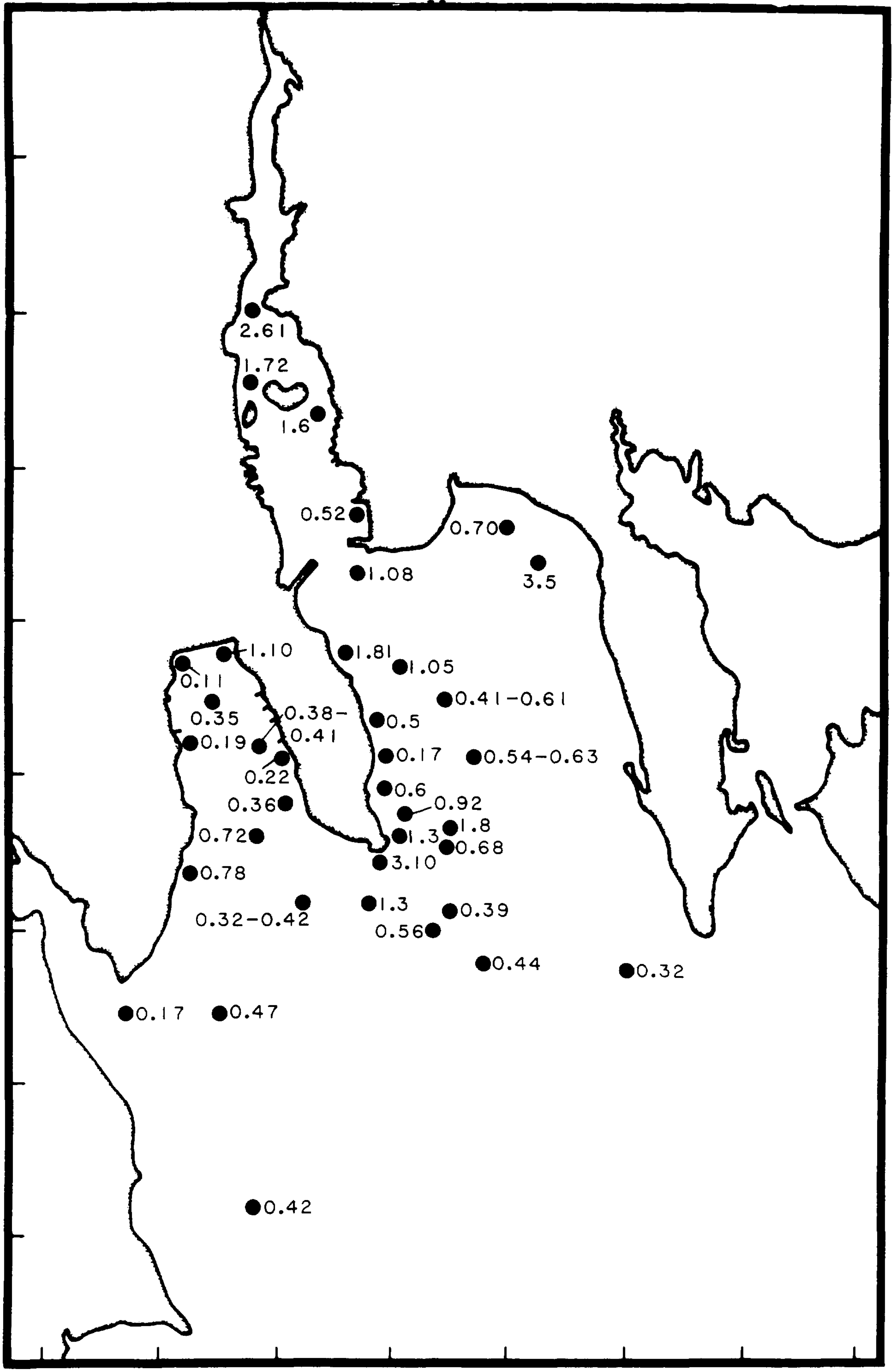


FIGURE 2.3.2. PCBs IN HARD-SHELL CLAMS (Mercenaria mercenaria) (ppm).

Generally PCB concentrations in tissues of hard-shell clams are lower than those in tissues of most other benthic fauna sampled to date.

There is a substantial body of information about PCB contamination of lobsters (Homarus americanus) from the area. Much of the site-specific data from the Metcalf and Eddy database are summarized in Figure 3.2.3. There were some samples from most areas inside the fishery Area Number 3 closed to lobster fishing that contained PCB concentrations in excess of the 5 ppm action level. It should be noted that the lobster digestive gland (considered a delicacy locally) often contains up to ten-fold higher concentrations of PCBs than does the muscle tissue. Very limited data are available for lobsters from inside the hurricane barrier, probably because they are rare there and difficult to catch.

Winter flounder (Pseudopleuronectes americanus) are abundant throughout the area south of Popes Island and generally are moderatley heavily contaminated with PCBs (Figure 3.2.4). Many samples contain concentrations in excess of the FDA action level.

The current data on PCB contamination of marine species from the area which will be used in the food-chain model are useful as an indication of the PCB concentration range to be expected in the current program. Only limited data are available, however, on the PCB isomer composition and ratios in the animal tissues. Recent studies by John Farrington of W.H.O.I. and Paul Boehm of Battelle New England have shown that lobsters and flounder, but apparently not bivalve molluscs, selectively metabolize and excrete certain PCB isomers and retain others. As a result, the PCB composition in the tissues of the animals is quite different than that in the ambient sediments and water column (Figures 3.2.5 and 3.2.6). This is a major reason why we propose to model four PCB pseudocomponents instead of a single generic mix (e.g. Aroclor 1254).

Several investigators at W.H.O.I. have ongoing Sea Grant research projects dealing with the New Bedford Harbor PCB problem. Although much of this data is unpublished and therefore not, strictly speaking, available for direct use in the modeling, it will be very useful as a check and verification of the data we will collect. For instance, mussel transplant studies being performed by Dr. Farrington's group can be used to verify PCB bioaccumulations predicted by our food-chain model.

The Metcalf and Eddy database contains some heavy metals data for sediments from the inner and outer harbor. These data are derived from the work of Summerhayes et al. (1977). The highest ocncentrations of most metals occur in sediments collected about 1,000 feet south of the Route I-195 bridge from the Acushnet River. The

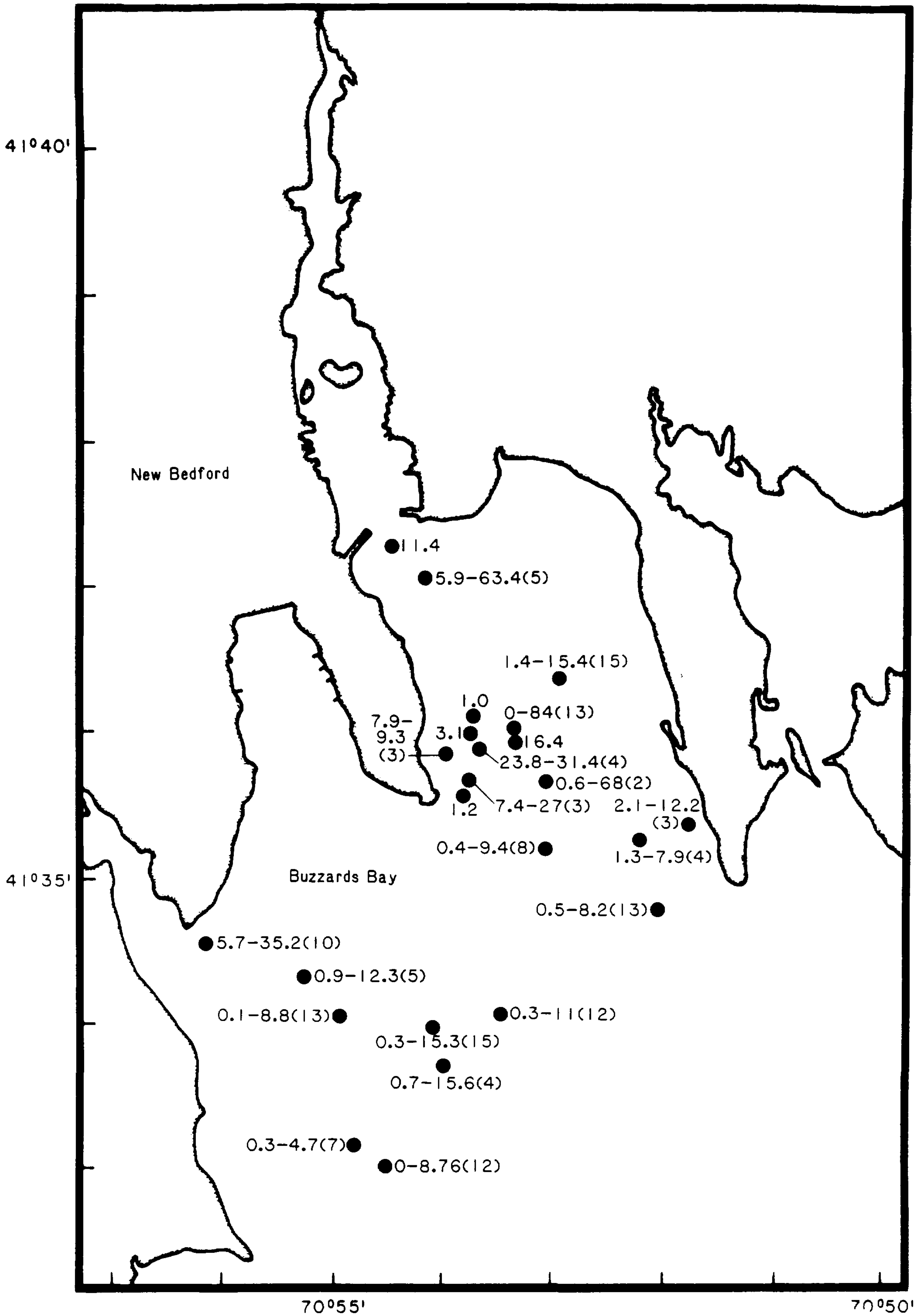


FIGURE 2.3.3. PCBs IN LOBSTERS (Homarus americanus) (ppm wet wt.).

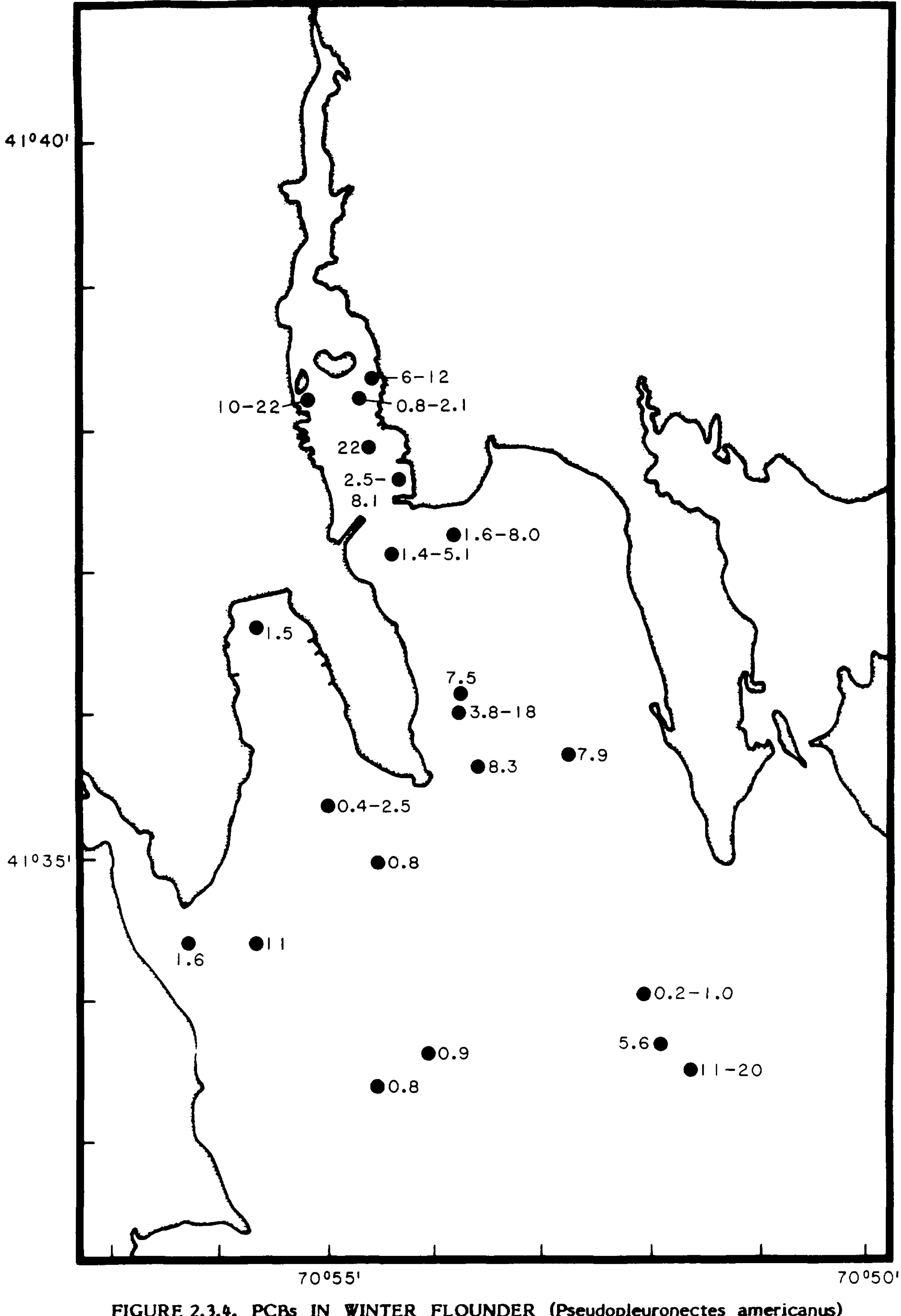


FIGURE 2.3.4. PCBs IN WINTER FLOUNDER (Pseudopleuronectes americanus) (ppm wet wt.).

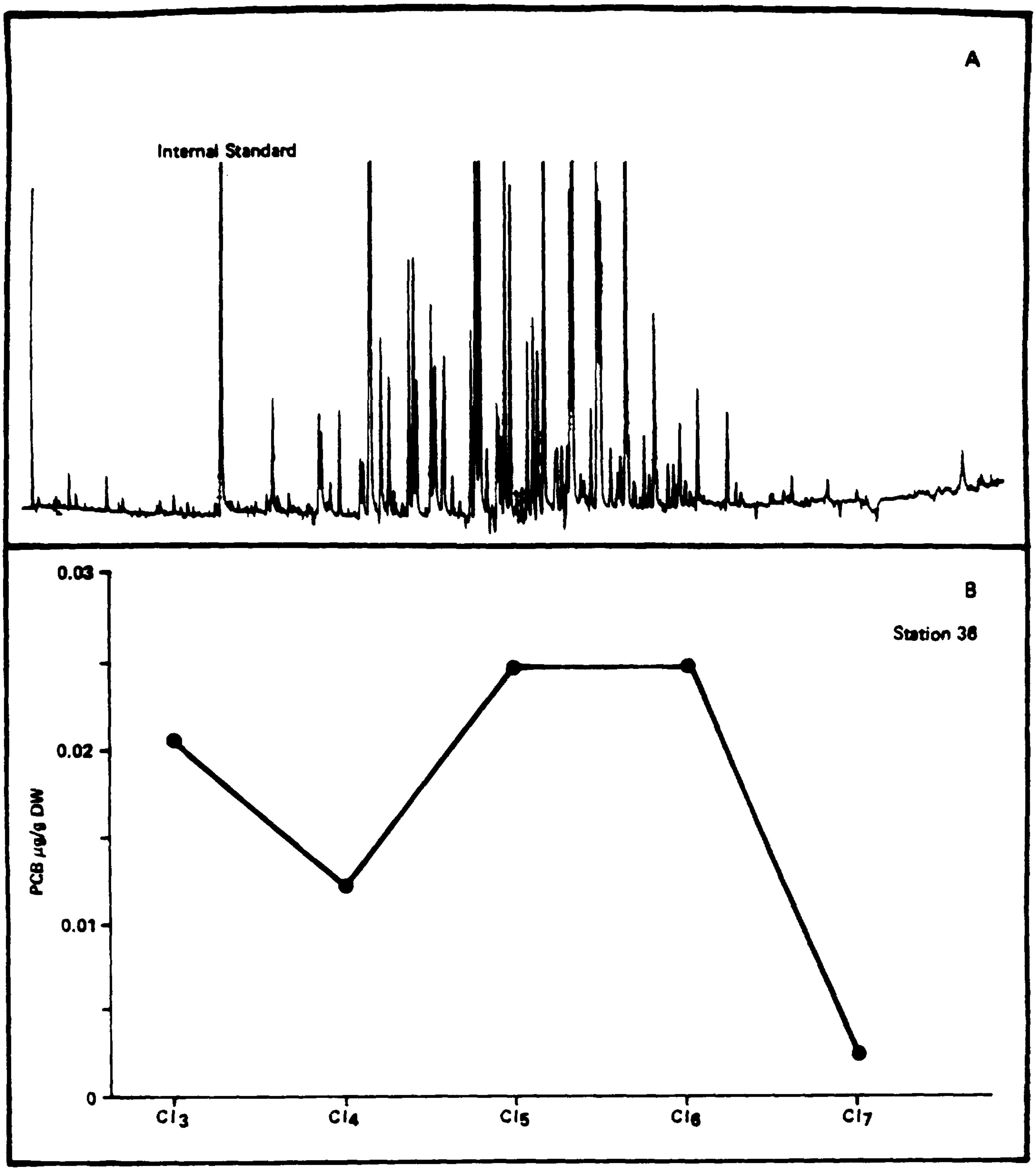


FIGURE 2.3.5. CAPILLARY GC/ECD TRACE (A) AND ISOMERIC COMPOSITION (B) OF TYPICAL BUZZARDS BAY SEDIMENT SAMPLE.

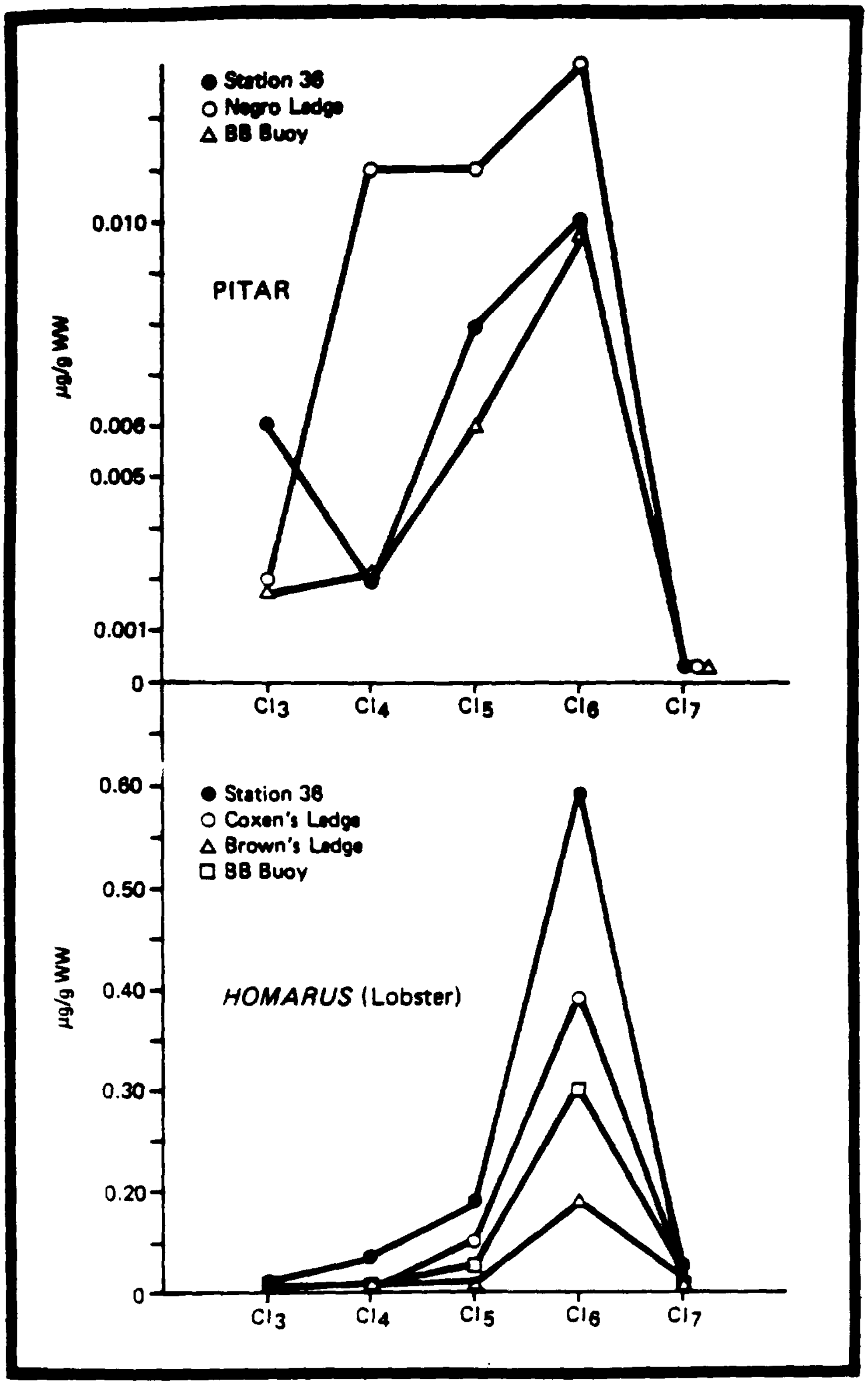


FIGURE 2.3.6. PCB ISOMERIC DISTRIBUTIONS FOR CLAMS (<u>Pitar</u>) and LOBSTERS (<u>Homarus</u>).

distribution of lead is slightly different, with highest concentrations in sediments just north of the Coggeshall Street bridge and off the Clark's Point sewage treatment plan outfall. Much of the lead may be derived from combustion of leaded gasoline and street runoff. There are no readily available data on concentrations of the metals of concern (mainly copper, chromium, lead, zinc, and cadmium) in biota from the Acushnet River estuary and Buzzards Bay.

2.3.2 Recent Studies

In a recent study, EPA and the Coast Guard studied concentrations of dissolved and particulate PCBs in the water column at the Coggeshall Bridge over three tidal cycles, including a storm event (EPA, 1983). The study was performed carefully and shows that there is a significant efflux of PCBs from the upper Acushnet River into New Bedford Harbor. Estimated net transport of PCBs out of the Acushnet River during the three tidal cycles studied were 2.5, 1.3 and 1.4 kg. The authors estimated that the annual export of PCBs from the Acushnet River to New Bedford Harbor is between 424 and 972 kg (833-2,138 lbs). These estimates verify the very serious magnitude of the PCB problem in the Acushnet River/New Bedford Harbor system.

2.3.3 Hydrographic Background

The existing data demonstrate that for considerations of sediment transport and mixing, the major response of the Bay and Outer Harbor regions is to storm systems. It is clear that under all conditions the Outer Harbor is forced by the conditions in Buzzards Bay and that the Inner Harbor is forced by this sytem. The available data indicate that the Bay and Outer Harbor forcing can be reasonably well-characterized from local measurements. This analysis is ongoing. Little is known about the response of the Bay to forcing by the surrounding Continental Shelf conditions, but for the purposes of deriving an empirical forcing function based on data from Buzzards Bay only, this lack of knowledge of the response may not be a problem.

In spite of a reasonably well-characterized sea level response, the current response to tidal and wind forcing is not well-known. Selected near-bottom flow measurements in the Outer Harbor by W. Grant and B. Butman of W.H.O.I. and U.S.G.S. and in the center of the Bay give a clear indication of the critical processes and magnitudes of near-bottom flows at these points. These data could be compared in detail to selected events. However, the flow in the Inner Harbor and the detailed vertical distribution of currents over the water column in the Inner or Outer Harbor or the entire Bay are unknown. This gap may be of critical importance to close because there is an indication of onshore bottom flow and offshore surface flow which results in a picture of New Bedford Harbor as a "leaky sink" for pollutants.

The overall circulation in Buzzards Bay outside of New Bedford Harbor is also poorly known. This flow will determine the transport of pollutants from the "leaky sink" to the surrounding New England coastal system. There are many indications that the flow out of New Bedford Harbor hugs the coast along the northwest shore of Buzzards Bay and flows southerly out of Buzzards Bay. This picture has limited support from patterns of density-driven circulation inferred from hydrography and from known tidal currents. This picture is also consistent with Mussel Watch data of J. Farrington of W.H.O.I. However, the overall role of storms in this system and of local wind-driven circulation is unknown.

The data clearly show that sediment resuspension occurs around the Bay and in the Outer Harbor from the action of surface waves, since the tidal, low frequency, and mean flow field cannot generate sufficient stress to resuspend much sediment. Wave action sufficient to resuspend sediment in shallow water can be generated by local sea breezes in the summer and early fall. Over most of the Outer Harbor and Buzzards Bay, only storm waves can resuspend the sediment. Thus, it appears that the "leaky sink" picture of the Inner Harbor must be examined for conditions during storms to examine the net exchange between large volumes of sediment carried into the harbor by bottom flows during storms and carried out of the Inner Harbor by the same storms.

The data available also define clearly the basic physics which must be resolved in any circulation and mass transport modeling of parts of the Bay and Outer Harbor. First at different times of the year, vertical and horizontal gradients in the density field are pronounced. The effect of local topography on the current is evident. Thus, the model must include advection, and the influence of stratification on any modeling of vertical stress divergences. In addition, the mean friction has been shown to be influenced by surface gravity waves through wave-current interaction and therefore this effect must be included in models of the stress divergence. Finally, both wind-driven and tidal-driven flows must be included in modeling.

From existing data on tidal currents, hydrography, bathymetry and satellite pictures, the following very simplified picture of circulations and exchanges exist in the

Bay. A relatively well-mixed region in the center of the Bay from near Cleveland Ledge to south of New Bedford Harbor (Figure 2.3.7). Possibly, there is a net counter-clockwise circulation. The exchange of water into the Bay from the holes along the southeast side is small. The islands act as a block and because of the phase difference between ebb and flood tides in Vineyard Sound and Buzzards Bay, little tidal-induced flow comes into the Bay from Vineyard Sound. Bay topography may help a northeastward flow into the Bay along the southeastward side and a southwestward flow out of the Bay along the northwest side of the bay. This above pattern has not been tested and is simply a suggested circulation which can act as an initial guide to planning further data taking. Figure 2.3.7 provides a summary schematic.

Additional relevant hydrographic information for the estuary and bay are summarized in Table 2.3.2.

2.3.4 Physical/Chemical Properties of PCBs and Metals

There is a fairly large volume of published data dealing with the physical chemistry (aqueous solubility, partition coefficients, volatility, etc.) of various PCB mixtures (e.g., Aroclors) and several of the metals of concern in New Bedford Harbor. Aqueous solubilities of PCB isomers are difficult to measure empirically, and as a result published values vary widely (e.g., Tulp and Hutzinger, 1978; Lee et al., 1979; Mackay et al., 1980a). Typical published solubility values range from 5,900 parts per billion (ppb) for dichlorobiphenyl to 0.016 ppb for decachlorobiphenyl. Adsorption/desorption kinetics and partition (or distribution) coefficients for several PCB isomers and different types of suspended particles have been determined (Dexter and Pavlou, 1975; Karickhoff et al., 1979; DiToro and Horzempa, 1982; DiToro et al., 1982). Evaporation and vapor behavior have been studied (Hague et al., 1974; Mackay et al. 1980b). Relationship between octanol/water partition coefficients and bioaccumulation also has been studied extensively (Leo, 1971; Mackay et al., 1980b; Geyer et al., 1982).

There also is a very substantial published literature dealing with chemical speciation, solubility and adsorption/desorption of metals, including copper, in marine and estuarine environments. Copper speciation in seawater has been studied extensively (e.g., Zirino and Yamamoto, 1972; Battey and Gardner, 1978). Battelle recently applied the goechmical model MINTEQ to predict the relationship of physical/chemical factors to

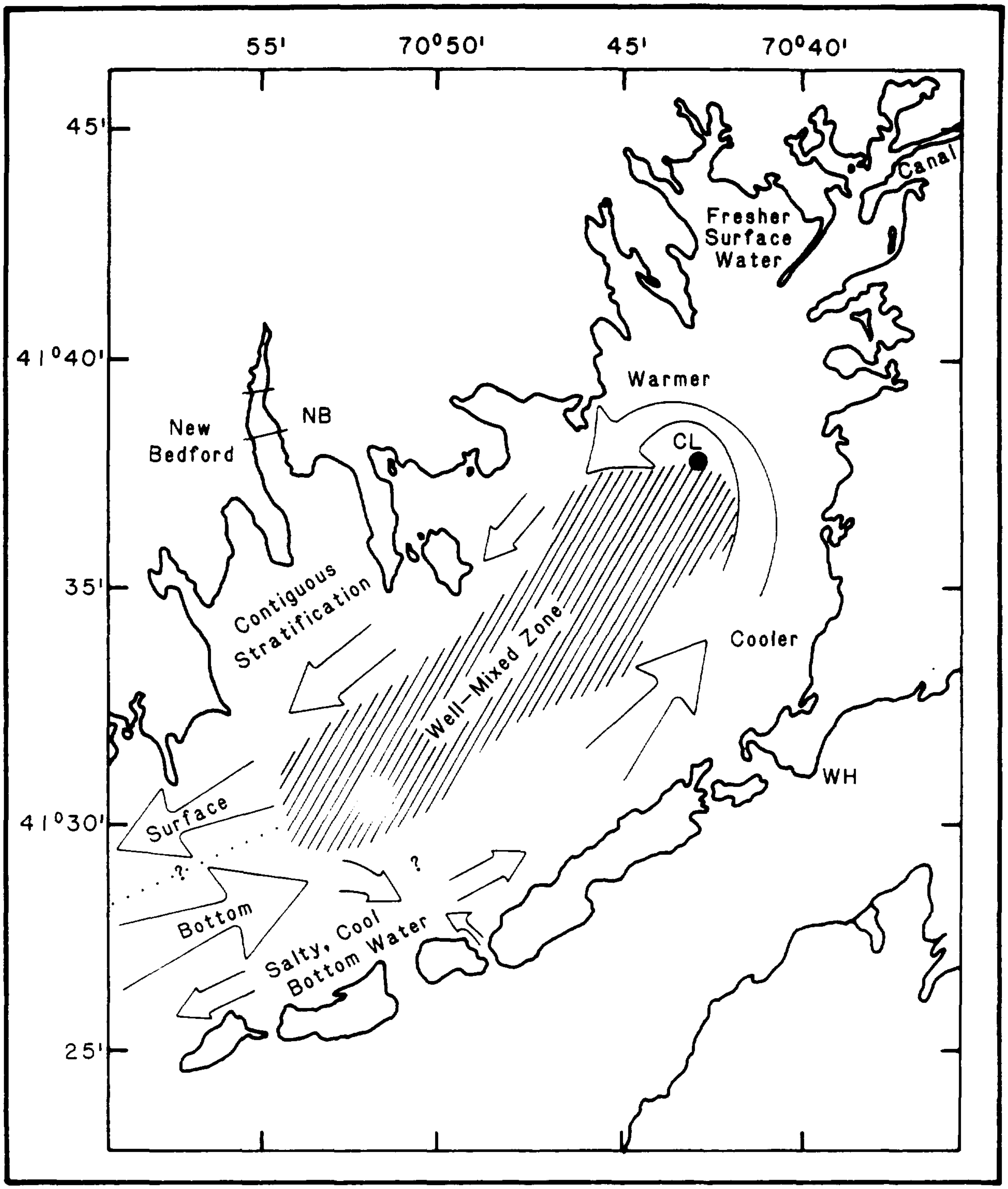


FIGURE 2.3.7. POSTULATED CIRCULATION AND MIXING IN BUZZARDS BAY

TABLE 2.3.2. SUMMARY OF SOME IMPORTANT HYDROGRAPHIC PARAMETERS FROM THE ACUSHNET RIVER/NEW BEDFORD HARBOR/BUZZARDS BAY SYSTEM.

Mean Tital Range: 3.7 ft. (1.11 m)

Spring Tides: to 4.6 ft. (1.38 m)

Tidal Currents, Buzzards Bay: generally less than 50 cm/sec.
Harbor Approaches: generally less than 25 cm/sec.
Harbor Entrance: up to 122 cm/sec.

Wind-driven Waves: up to about 6 ft. (1.8 m) mainly from the south and southwest.

Suspended Matter in Harbor: Surface, 1-6 mg/l, 30-65% combustible
Bottom, 3-7.5 mg/l, 12-40% combustible
Maximum, 31.5 mg/l during storms

Estimated Sedimentation Rate in Inner Harbor: 1.7-4 cm/year since 1966
0.2-1 cm/year before 1966

Salinity in Inner Harbor: Surface, 23-30 o/oo
Bottom., 29.5-30.7 o/oo

Salinity in Outer Harbor: Surface, 26.8-30.4 o/oo
Bottom, 28.3-30.7 o/oo

Differences in salinity between surface and bottom water rarely exceed 1 o/oo

Lowest recorded salinity in harbor: 23.2 o/oo

Discharge of Acushnet River to New Bedford Harbor is 0.02-0.74 cubic meters/second.

copper speciation and toxicity in aquatic systems (Cowan, 1984). Factors affecting the adsorption/desorption of copper and other metals from deposited and suspended sediments have been documented (Payne and Pickering, 1975; Patrick et al., 1977; Luoma and Bryan, 1981; Hunt and Smith, 1983). Earlier literature on copper in the marine environment was reviewed by Schmidt (1978).

Despite the extensive published literature, some site-specific data are required for the New Bedford Harbor modeling effort. Empirical measurements of adsorption/desorption and partition coefficient parameters for PCB pseudocomponents and copper, using site sediments will provide much more accurate and reliable values for input to the models, than would use of even the most reliable literature values.

2.3.5 Local Marine Biota

Although there have been few studies of the marine fauna and flora of the Acushnet River/New Bedford Harbor system per se, the fauna of Buzzards Bay/Long Island Sound in general and of several nearby estuaries (e.g., Narragansett Bay) are well-known. The marine fish fauna is similar to that of Massachusetts Bay and Long Island Sound (Bigelow and Schroeder, 1953; Oviatt and Nixon, 1973; Hoff and Ibara, 1977). Dominant demersal fish of the estuary and bay include winter flounder, Pseudopleuronectes americanus, American eel Anguilla rostrata, scup Stenotomus chrysops, summer flounder Paralichthys dentatus, windowpane flounder Scophthalmus aquosus, and tautog Tautoga onitis. Important invertebrate demersal and epibenthic fauna include lobsters Homarus americanus, spider crabs Libinia emarginata, rock crabs Cancer irroratus, mussels Mytilus edulis, oysters Crassostrea virginica and limpets Crepidula fornicata. The benthic infauna have been studied fairly extensively (Sanders, 1958, 1960; McCall, 1977) and sediment-biota interactions have been studied (Rhoads, 1967; Rhoads and Young, 1970; Driscoll, 1977). Muddy sediments in Buzzards Bay are dominated by the polychaete Nephthys incisa, the bivalve mollusc Nucula proxima and the snail Turbonilla sp. Sandy sediments have a different fauna dominated by the polychaetes Glyceria americana and Nephthys bucera, the amphipods Ampelisca spinipes and Byblis serrata and the bivalve mollusc, Cerastoderma pinnulatum. The hard-shell clam Mercenaria mercenaria is extremely abundant in low intertidal and shallow subtidal areas of Buzzards Bay, including New Bedford outer harbor. DeLorenzo reported M. mercenaria as the dominant macroinfaunal animal collected at most stations in his survey of PCB contamination of New Bedford Harbor marine biota. The soft-shell clam, Mya arenaria is abundant in intertidal muddy sand sediments near and in the harbor.

2.3.6 Biological and Bioenergetic Database for Species of Concern

The indigenous species of marine animals which will be considered in the food-chain model are winter flounder Pseudopleuronectes americanus, lobster Homarus americanus and hard-shell clams Mercenaria mercenaria. Model prey organisms for the flounder and lobsters will include rock crabs Cancer irroratus, spider crabs Libinia emarginata, mussels Mytilus edulis, and infaunal polychaetes.

The hard-shell clam Mercenaria mercenaria inhabits shallow marine sediments along the eastern and Gulf coasts of North America from Nova Scotia to Yucatan and supports important commercial fisheries, particularly in the northern part of its range. Its ecology is well-known (Carriker, 1961). Growth rate and bioenergetics have been studied thoroughly (Tenore et al., 1973; Tenore and Dunstan, 1973; Hibbert, 1977; Epifanio, 1979), and these data can be used directly for bioenergetic parameters for the food-chain model.

The American lobster, Homarus americanus is an extremely important commercial species whose range extends from Labrador to North Carolina and from shallow coastal waters to the continental slope and submarine canyons (Galtsoff, 1937). Inshore populations appear to make only small-scale seasonal migrations in response to water temperature changes (Morrissey, 1971). In Buzzards Bay, there may be two populations, a non-migrating inshore population, and an inshore-offshore migrating population. Growth rate (Mauchline, 1977; Campbell, 1983) and bioenergetics (Logan and Epifanio, 1978; Capuzzo, 1981) of lobsters have been studied and these studies will provide useful data for use in the food-chain model.

The geographic range of the winter flounder Pseudopleuronectes americanus extends from Labrador to Georgia (Bigelow and Schroeder, 1953). It is particularly abundant in coastal waters of New England and on Georges Bank where it supports large, economically important commercial and sport fisheries. Available evidence, reviewed recently by Klein-MacPhee (1978) and Van Guelpen and Davis (1979) suggests that inshore populations of winter flounder remain in shallow coastal waters as long as water temperatures do not become stressfully high or low. Although winter flounder do migrate, it is to a limited extent and they do not range widely, at least in Massachusetts coastal waters (Howe and Coates, 1975; Pierce and Howe, 1977). Available data on the biology of winter flounder have been summarized by Klein-MacPhee (1978). Feeding habits, growth, and bioenergetics of winter flounder have been studied extensively (Tyler and Dunn, 1976; Klein-MacPhee, 1978; Macdonald, 1983).

Mytilus edulis is probably the most thoroughly studied marine bivalve mollusc. Much of the relevant growth and bioenergetics data is summarized in a book (Bayne, 1976). Much less information is available on the growth and bioenergetics of spider crabs Libinia emarginata, rock crabs Cancer irroratus and infaunal polychaetes (Chambers and Milne, 1975; Neuhoff, 1979).

2.3.7 PCBs and Copper Bioaccumulation Database for Food-Chain Species

There is relatively little published data dealing with the bioaccumulation of PCBs and copper from water and food by the marine species included in our food-chain model. However, there is extensive published information for closely-related marine species. McLeese et al. (1980) studied bioaccumulation of PCBs in lobsters from consumption of contaminated mussels. Efficiencies of uptake of tetrachloro- and hexachlorobiphenyls from food ranged from 40-75 percent. Hard-shell clams were able to accumulate small amounts of PCBs from contaminated sediments (Rubinstein et al., 1983), while infaunal nereid polychaetes were able to accumulate significant amounts of PCBs from contaminated food and sediments (Goerke and Ernst, 1977; Fowler et al., 1978; McLeese et al., 1980). Mussels selectively retain the more highly chlorinated PCBs in their tissues (Calambokidis et al., 1979). Farrington (personal communication) currently is performing bioaccumulation experiments with caged mussels in outer New Bedford Harbor and Buzzards Bay, from which in situ bioaccumulation factors will become available. Bioaccumulation factors for several PCB isomers in Mytilus edulis were reported by Geyer et al. (1982). Studies of copper bioaccumulation and dynamics have been performed with winter flounder (Fletcher and King, 1978), mussels (Calabrese et al., 1984) and infaunal polychaetes (Luoma and Bryan, 1982; Windom et al., 1982).

Although PCB-degrading bacteria are associated with PCB-contaminated sediments, their rate of PCB degradation often is nutrient limited (Sayler et al., 1978). The rate of loss of sediment PCBs by this route probably is sufficiently low, particularly in the heavily contaminated sediments of the inner harbor, that it does not need to be considered in the physical/chemical model.

2.4 DATA USAGE

There are three major uses for the data and conclusions generated in this modeling program.

1. The modeling will predict the effects of different remedial actions on the distribution and long-term concentration trends of PCBs and metals in the Acushnet River/New Bedford Harbor/Buzzards Bay system. This information will enable EPA to select the most environmentally sensible remedial options.

2. It will enable us to preduct the rate of recovery (depuration) of key marine food-chain animals, including key indigenous commercial species, if remedial actions substantially reduce or eliminate important sources of PCB and metals contamination of Buzzards Bay.

3. The physical/chemical modeling will enable us to determine patterns of movements of PCBs and metals in the estuary and Bay system, which in turn may provide the basis for identifying probable point sources of the contaminants now present in different regions of the Acushnet River, New Bedford Harbor, and Buzzards Bay.

3. PROJECT DESCRIPTION

3.1 HYDRODYNAMICS

(Appended to the end of Section 3)

3.2 FIELD SAMPLING PROGRAM

3.2.1 Field Sampling Plan

Field smaples for chemical analysis will be collected at five different times during the modeling project: July, 1984, September, 1984, November-December, 1984 (both calm and storm conditions), and April, 1985. Sediment and water samples will be collected at 25 stations in September, 1984 to establish initial conditions for the physical/chemical model. Water samples will be collected at all these stations, and sediments will be collected at a subset of eight of these stations in July, November-December and April. The locations of these stations are shown in Figures 3.2.1-3.2.7. Ten of the stations are located in the Acushnet River and inner New Bedford Harbor. The remaining stations are located in the outer harbor and Buzzards Bay, including stations adjacent to the Cornell-Dubilier plant, near the sewage treatment plant outfall, and at the dredge material disposal site. Three stations are located at the Buzzards Bay boundary where current meters will be deployed from August to December. Biota samples will be collected from four areas indicated in Figure 3.2.8. These correspond to the fishery closure areas. The sampling schedule is summarized in Table 3.2.1. The July, 1984 and April, 1985 sampling trips are primarily for data collection for the food-chain model. An additional seasonal biota sample will be collected in November-December. The September and November-December sampling trips are scheduled to be concurrent with the moored array current meter study at the bay boundary and the drogue studies in the region of the outer harbor. They are primarily designed to collect data for the physical/chemical model. Vertical core samples will be collected at Stations 1, 6 and 7 during the September sampling trip. Station 1 is in the area of heaviest PCB contaminaiton. Station 6 is in an area of the harbor which never has been dredged. Station 7 is in the main ship anchorage area and has and will be subject to much dredging.

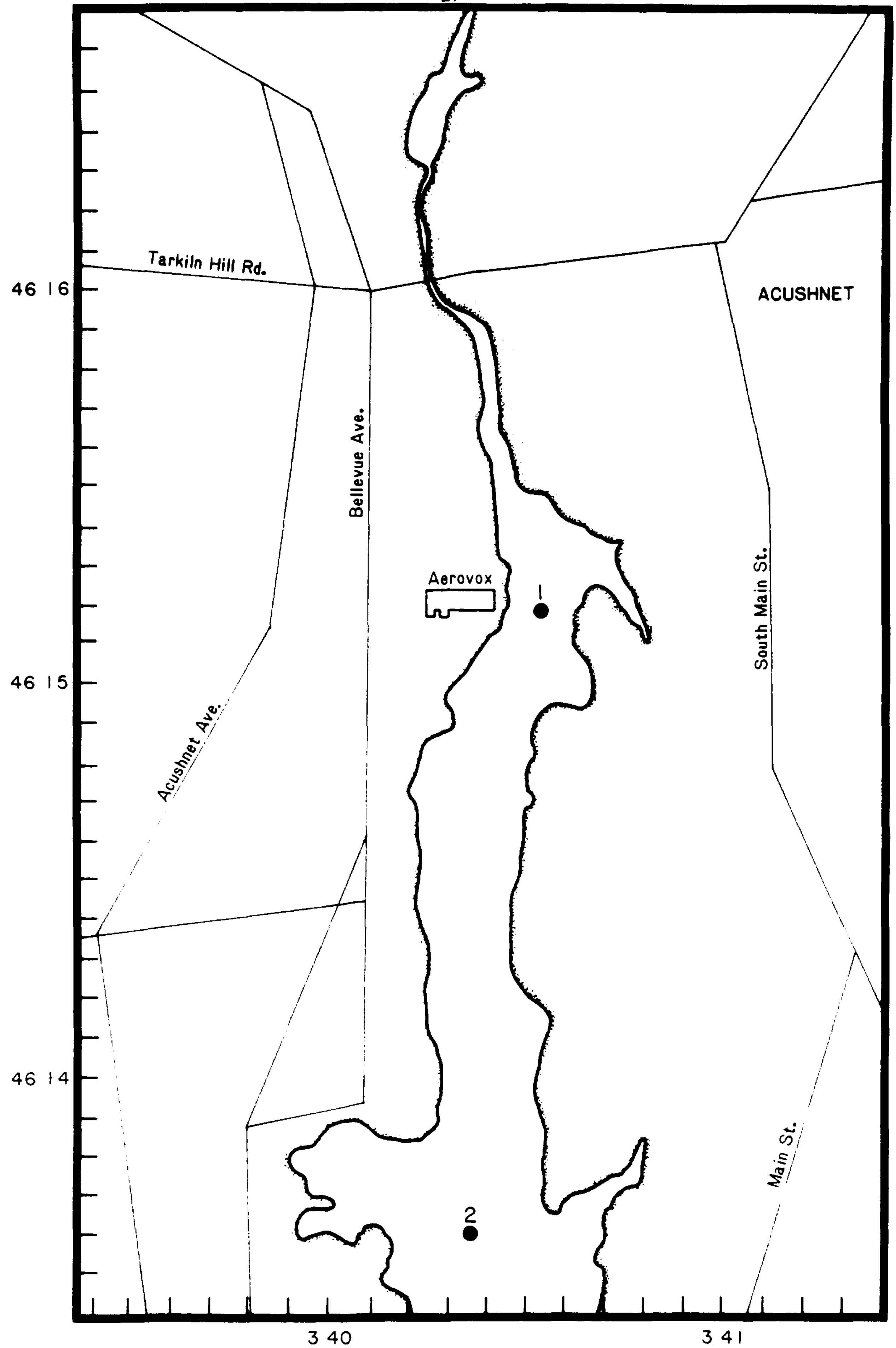


FIGURE 3.2.1. SEDIMENT SAMPLING STATIONS, JUNE-JULY, 1984

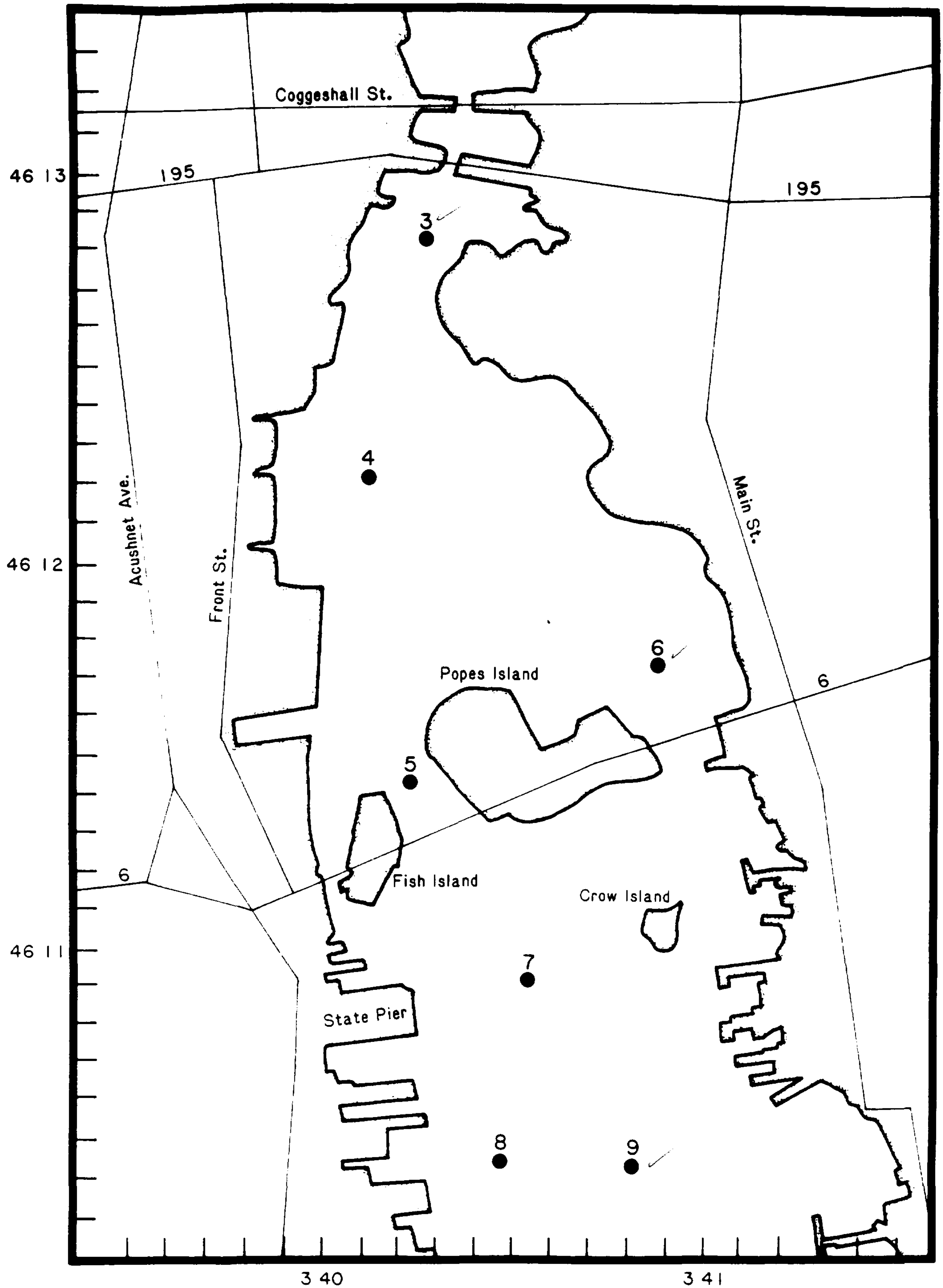


FIGURE 3.2.2. SEDIMENT SAMPLING STATIONS, JUNE-JULY, 1984

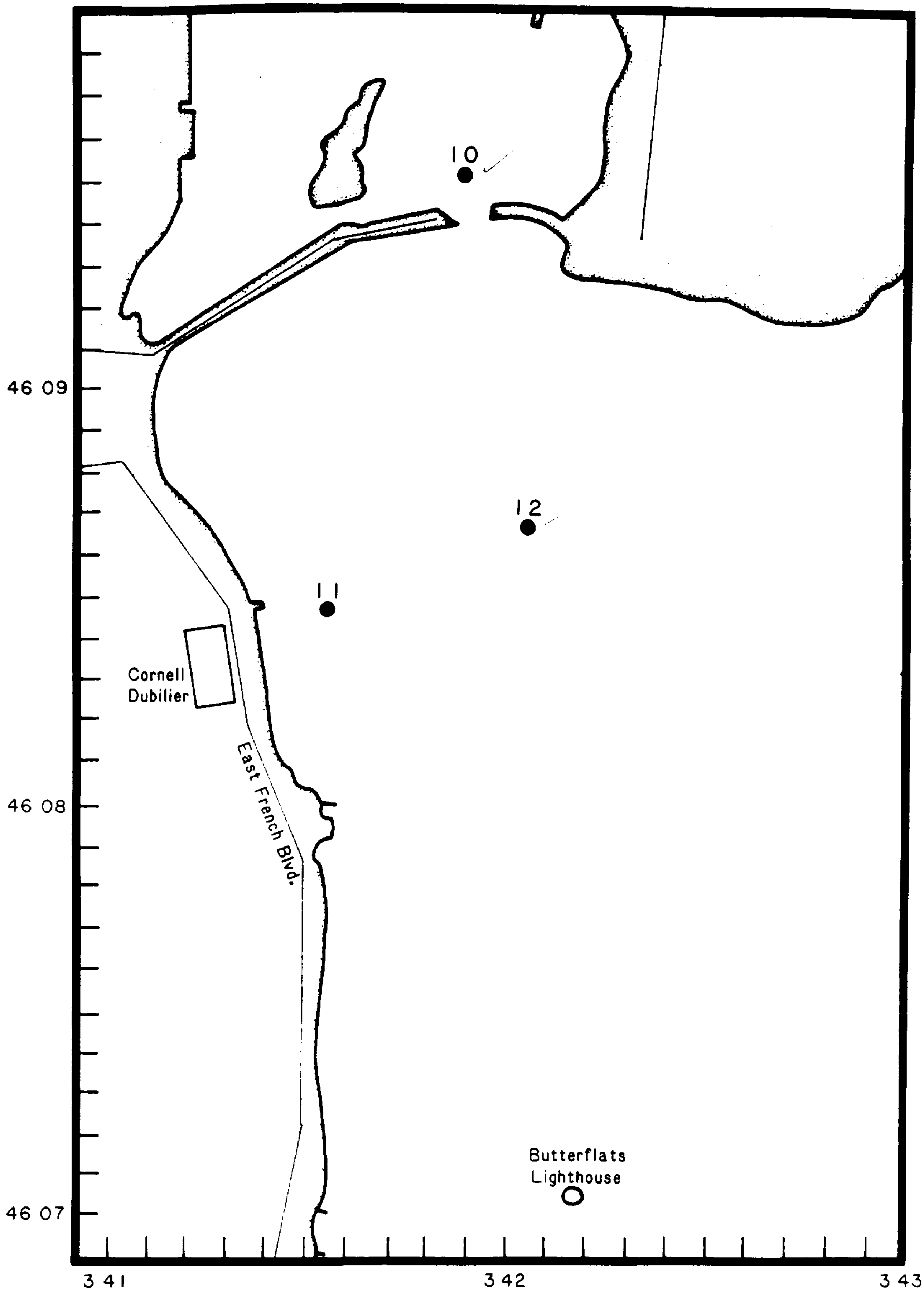


FIGURE 3.2.3. SEDIMENT SAMPLING STATIONS JUNE-JULY, 1984.

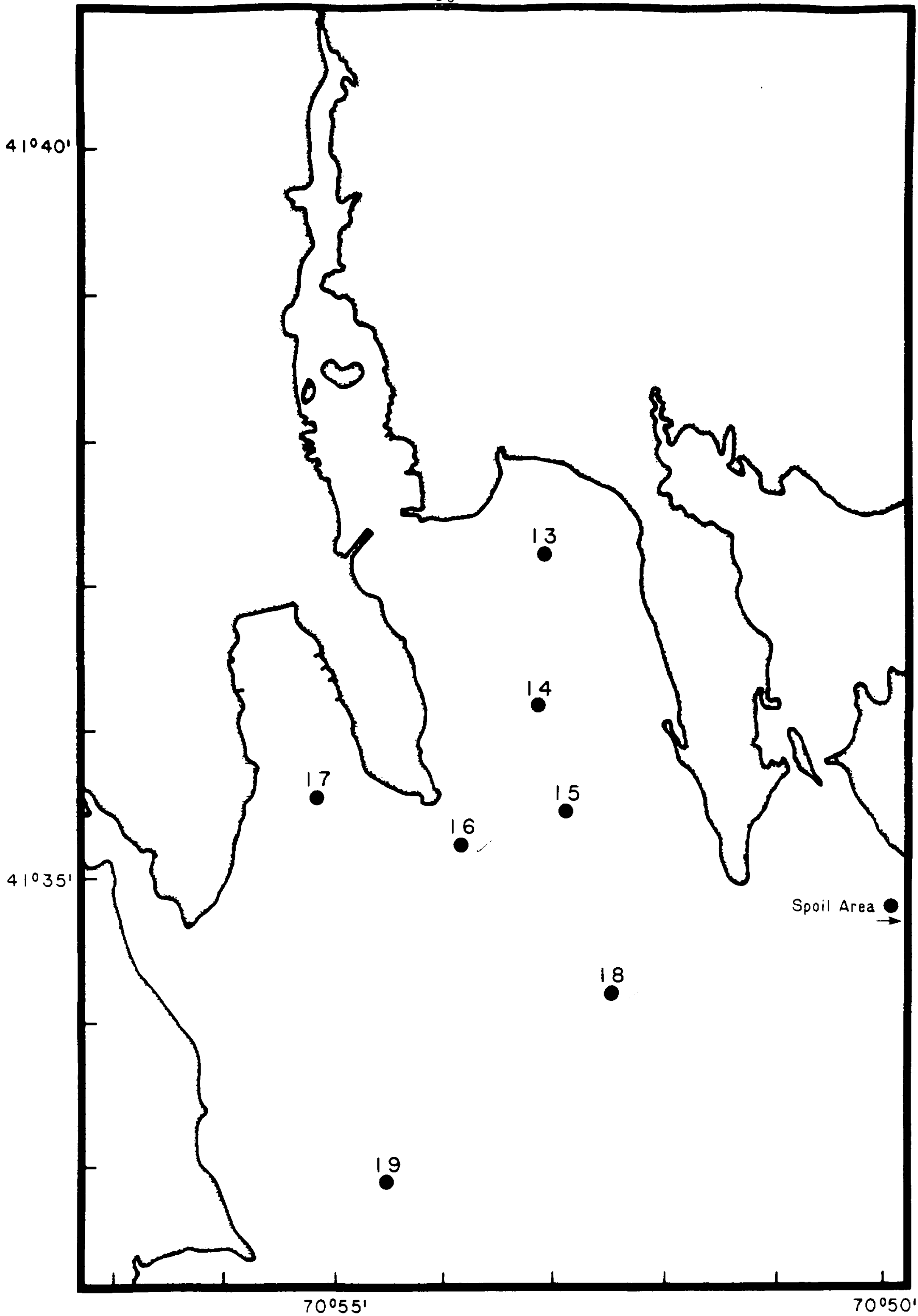


FIGURE 3.2.4. SEDIMENT SAMPLING STATIONS JUNE-JULY, 1984.

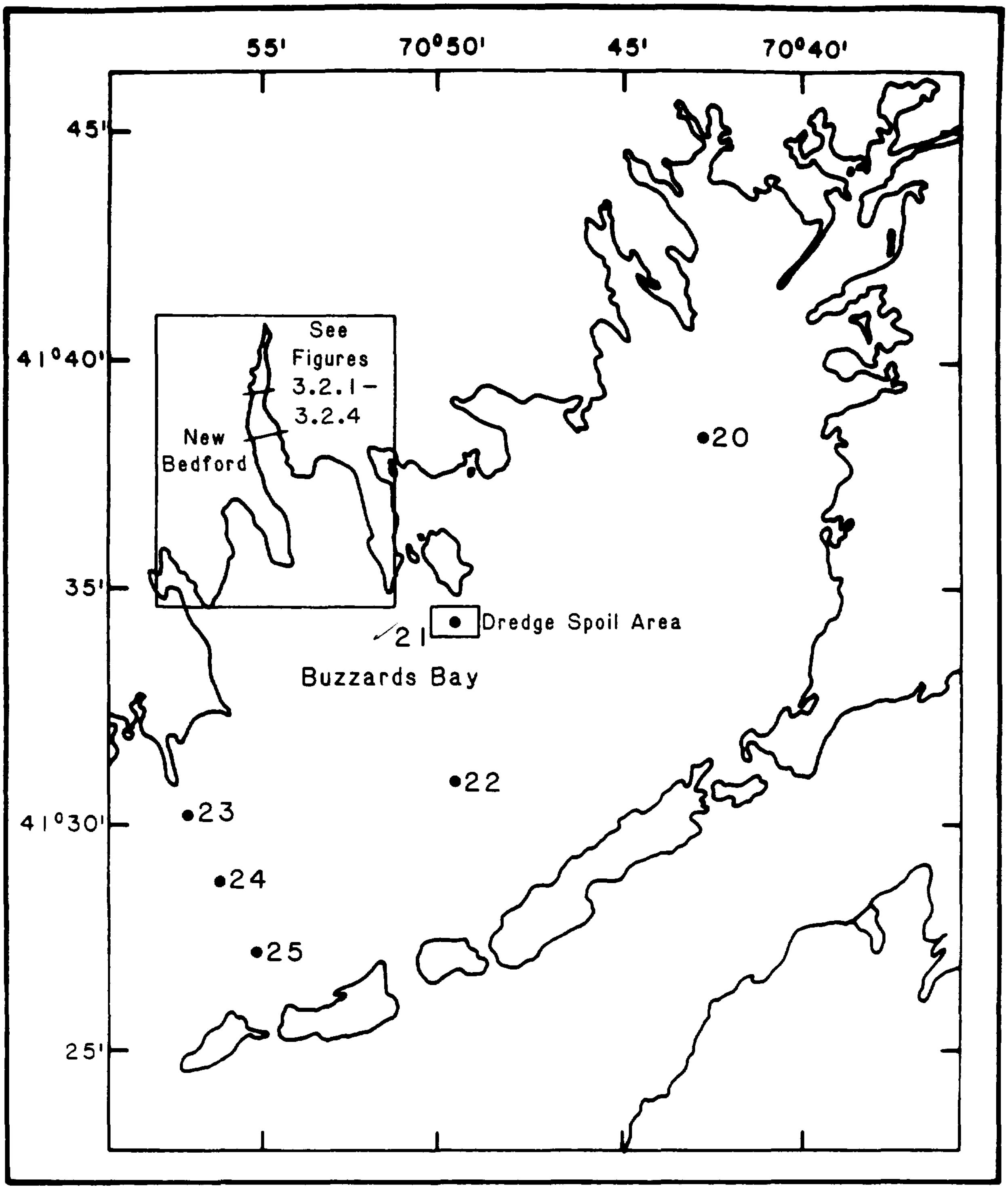


FIGURE 3.2.5. SEDIMENT SAMPLING STATIONS, JUNE-JULY, 1984

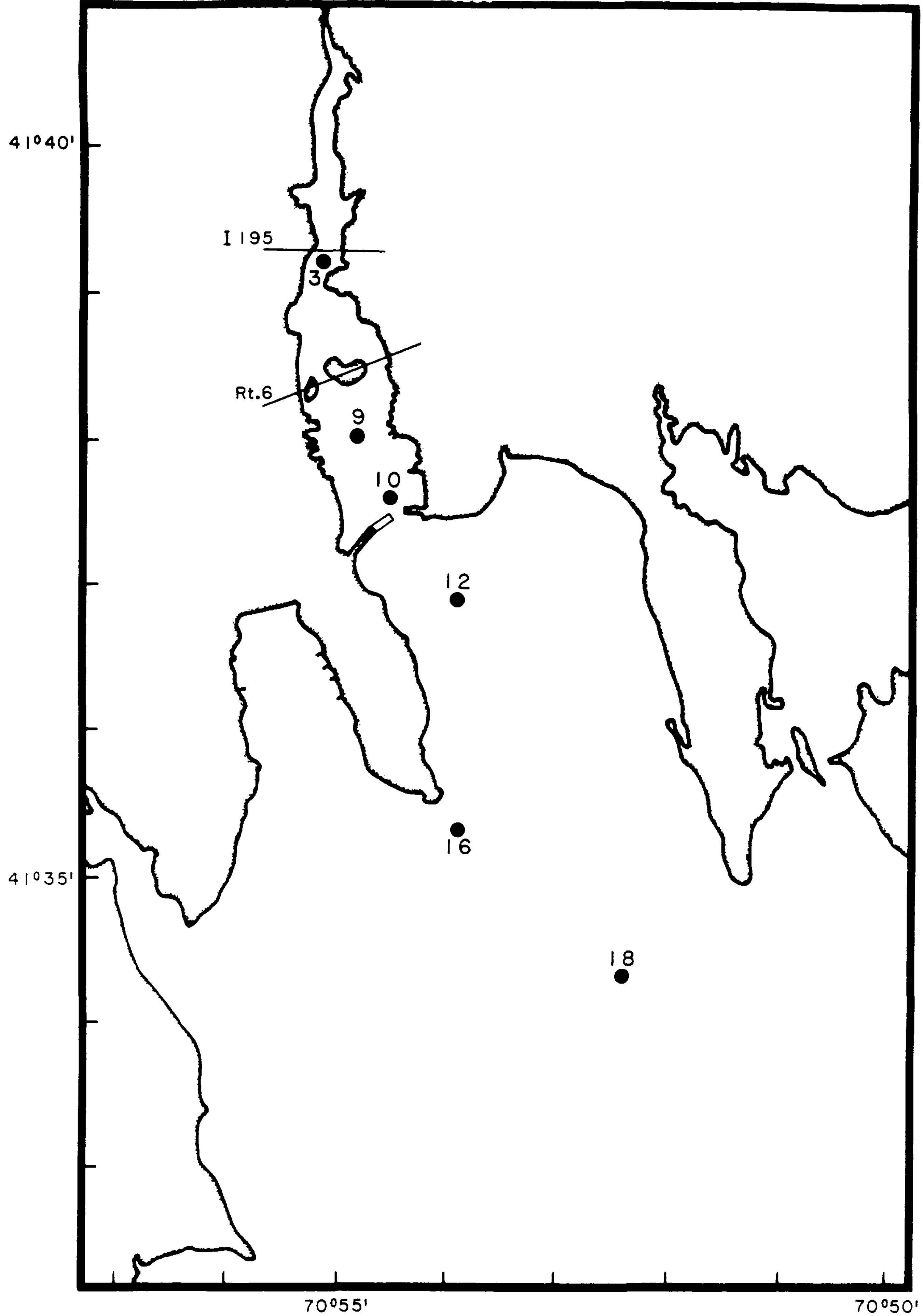


FIGURE 3.2.6. WATER SAMPLING AND SEASONAL SAMPLING STATIONS, 1984.

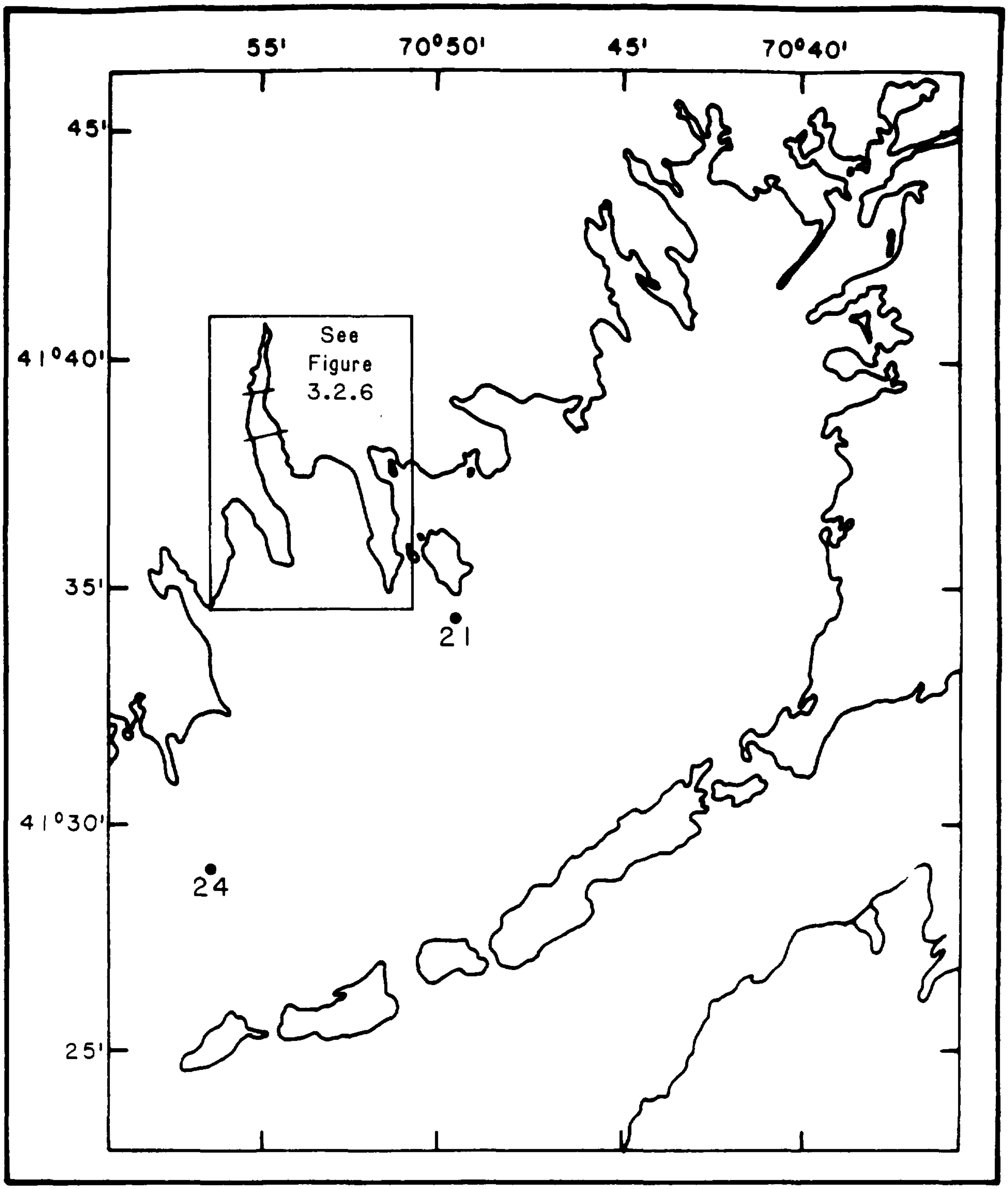


FIGURE 3.2.7. WATER SAMPLING AND SEASONAL SAMPLING STATIONS, 1984.

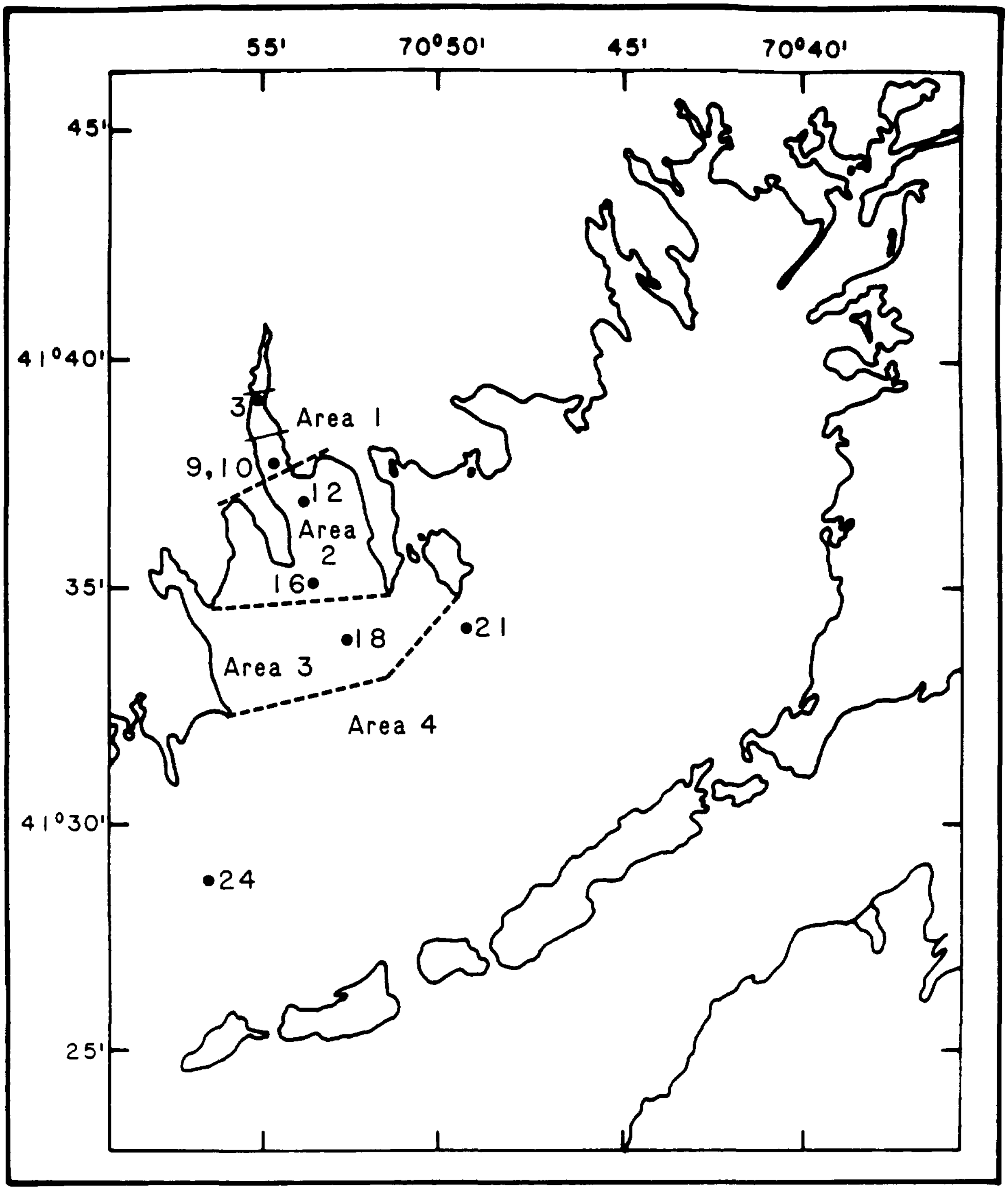


FIGURE 3.2.8. BIOTA SAMPLING AREAS AND CORRESPONDING SEDIMENT AND WATER COLUMN SAMPLING STATIONS.

TABLE 3.2.1. SAMPLING SCHEDULE

July 2-20, 1984	
Sediments:	
8 Stations x 2 Replicates x 1 Fraction	16
8 Stations x 1 Replicate x 4 Fractions	32
Subtotal	48
Water Column:	
25 Stations x 1 Depth x 1 Sample x 2 Fractions	50
Biota:	
Lobsters: 4 Areas x 3 Sizes x 3 Replicates	36
Flounder: 4 Areas x 3 Sizes x 3 Replicates	36
Clams: 4 Areas x 3 Sizes x 3 Replicates	36
Crabs: 4 Areas x 2 Sizes x 3 Replicates	24
Mussels: 4 Areas x 2 Sizes x 3 Replicates	24
Infauna: 4 Areas x 1 Size x 1 Replicate	4
Subtotal	160
Total Samples	**258**
September 10-28, 1984	
Sediments:	
22 Stations x 2 Replicates x 1 Fraction	44
22 Stations x 1 Replicate x 4 Fractions	88
3 Stations x 1 Replicate Core x 10 Sections x 2 Fractions	60
Subtotal	192
Water Column:	
8 Stations x 2 Water Depths x 4 Samples (1 Tidal Cycle) x 2 Fractions	128
18 Stations x 2 Water Depths x 1 Sample x 2 Fractions	72
3 Stations x 1 High-Volume Sample x 3 Fractions	9
Subtotal	209
Total September	**401**

TABLE 3.2.1. (Continued)

November 12 - December 7, 1984		
Sediments:		
8 Stations x 2 Replicates x 1 Fraction		16
8 Stations x 2 Replicates x 4 Fractions		32
	Subtotal	48
Water Column:		
8 Stations x 2 Water Depths x 4 Samples x 2 Fractions		128
17 Stations x 2 Water Depths x 1 Sample x 2 Fractions		68
	Subtotal	196
Lobsters: 4 Areas x 3 Sizes x 3 Replicates		36
Flounder: 4 Areas x 3 Sizes x 3 Replicates		36
Clams: 4 Areas x 3 Sizes x 3 Replicates		36
Crabs: 4 Areas x 2 Sizes x 3 Replicates		24
Mussels: 4 Areas x 2 Sizes x 3 Replicates		24
Infauna: 4 Areas x 1 Size x 1 Replicate		4
	Subtotal	160
November - December Storm Event		
Sediments:		
8 Stations x 2 Replicates x 1 Fraction		16
8 Stations x 2 Replicates x 4 Fractions		32
	Subtotal	48
Water Column:		
8 Stations x 2 Depths x 1 Time x 2 Fractions		32
	Subtotal	80
	Total November - December	**484**
April 15-19, 1985		
Sediments:		
8 Stations x 2 Replicates x 1 Fraction		16
8 Stations x 2 Replicates x 4 Fractions		32
	Subtotal	48
Water Column:		
25 Stations x 1 Depth x 1 Sample x 2 Fractions		50

TABLE 3.2.1. (Continued)

April 15-19, 1985 (Continued)

Lobsters: 4 Areas x 3 Sizes x 3 Replicates	36
Flounder: 4 Areas x 3 Sizes x 3 Replicates	36
Clams: 4 Areas x 3 Sizes x 3 Replicates	36
Crabs: 4 Areas x 2 Sizes x 3 Replicates	24
Mussels: 4 Areas x 2 Sizes x 3 Replicates	24
Infauna: 4 Areas x 1 Size x 1 Replicate	4
Subtotal	160
Total April 15-19, 1985	**258**

Summary of Analytical Field Samples

July, 1984	**259**
September, 1984	**401**
November-December, 1984	**484**
April, 1985	**258**
Lab Experiments	**-**
Samples for 4 PCB Pseudocomponents Plus 1 Metal	**1401**

3.2.2 Sediment and Water Column Sampling

3.2.2.1. Sediments. All sediment samples to be collected as part of the sampling program are outlined in Tables 3.2.2-3.2.4. All sediment field sampling will be performed aboard the RV Mya by Battelle personnel using a 3.3-inch (8.4 cm) diameter hydraulically-damped gravity corer made available by the U.S. Geological Survey, Woods Hole, Massachusetts. This corer has a knife edge nosecore and uses narrow (.094 inch) wall core tubing allowing the corer to penetrate with little disruption of sediment integrity, thus making it ideal for the collection of both undisturbed surface material and core samples to 50 cm. Use of the 3.3-inch corer increases the level of effort needed for the sediment sampling program (compared to grab sampling or other corers). However, it assures the collection of samples that most accurately reflect true bottom conditions and also simplifies the coring field program, in that the amount of at-sea processing will be limited to removal of overlying water, capping, and storing (Section 3.2.4). Splitting the sample and all further processing will be under controlled laboratory conditions. Use of the core barrel as the temporary sampling container will allow the sediment sampling program to progress without disruptions caused by immediate shipboard or laboratory processing. However, sediment samples will be completely processed within twelve hours of collection to minimize effects of pore water migration or oxidation reduction (Farrington, personal communication).

Use of the 3.3-inch diameter hydraulically damped gravity corer will help minimize the cross-contamination caused by the presence of contaminated material from "hot spots" contaminating sampler surfaces which in turn contaminate subsequent samples. Since a clean core barrel will be used for each lowering, the chances of this occurring are lowered. Further, the corer itself, including miniframe and plunger, will be cleaned between lowerings to remove mud and debris and the corer nosecore will be solvent washed between lowerings.

For all but three cores on which depth profile measurements will be performed, only the upper 0-5 cm layer of sediment will be subsampled and analyzed for either chemical contamination of gross sediment or of sediment compartment fractions (pore water, sand, silt and clay fractions). However, the remaining core material will be archived for the duration of the project so that it will be available in case reanalysis is necessary, or if sediment is needed for other parts of the project.

TABLE 3.2.2. SEDIMENT SAMPLING FOR TRACE METAL AND PCB ANALYSIS SECOND BOUNDARY CONDITIONS; STORM EVENT CONDITIONS, NOVEMBER-DECEMBER, 1984.

Modeling Information	Number of Stations	Replicates Per Station	Total Replicates	Fractions Per Replicate	Total Fractions Generaged	Sampling Gear
Gross Surface Sediment Characterization (Pore Water/Gross Dewatered Sediment)	8 (8)	2 (2)	16 (16)	2 (2)	64	Hydraulically damped gravity cores.
Surface Sediment (0-5cm) Compartment Differentia-ation (Pore Water, Sand, Silt,Clay, and Labile Material)	8 (8)	1 (1)	8 (8)	5 (5)	80 gravity cores.	Hydraulically damped
Grain Size Analysis, Total Organic Carbon						Subsample from all replicates.

TABLE 3.2.3. SEDIMENT SAMPLING FOR TRACE METAL AND PCB ANALYSIS INITIAL CONDITIONS, SEPTEMBER, 1984.

Modeling Information	Number of Stations	Replicates Per Station	Total Replicates	Fractions Per Replicate	Total Fractions Generaged	Sampling Gear
Gross Surface Sediment Characterization (Pore Water/Gross Dewatered Sediment)	25	2	[illegible]0	2	100	Hydraulically damped gravity corer.
Surface Sediment (0-5 cm), Compartment Differentiation (Pore Water, Sand, Silt,Clay, Labile Material)	25	1	25	5	125	Hydraulically damped gravity corer.
Depth Profile	3	1	3			Hydraulically damped gravity corer
Grain Size, Total Organic Carbon						Subsample from all replicates.

TABLE 3.2.4. SEDIMENT SAMPLING FOR TRACE METAL AND PCB ANALYSIS, BIOLOGICAL SAMPLING TRIPS, JULY, 1984, APRIL, 1985

Modeling Information	Number of Stations	Replicates Per Station	Total Replicates	Fractions Per Replicate	Total[a] Fractions Generated	Sampling Gear
Gross Surface Sediment Characterization (0-5 cm) (Pore Water/Gross Dewatered Sediment)	8	2	16	2	32	Hydraulically damped gravity corer
Surface Sediment, (0-5 cm) Compartment Differentiation (Pore water, Sand, Silt, Clay, Labile Material)	8	1	8	5	40	Hydraulically damped gravity corer
Grain Size Analysis, Total Organic Carbon						Subsample from all REPLICATES

3.2.2.2. Water Column Sampling. Water will be collected both for analysis of area wide chemical contamination and to be used as a medium in other analyses (i.e. partitioning experiments, wet sieving sediments (Table 3.2.5). The method to be used to collect water samples is a non-contaminating submersible pump which will pump water from any desired depth through teflon tubing to the ship for processing or collection. The pump has an operating depth range from 0-30 m which encompasses the range of depths expected in the survey area.

The pumping system will be configured so that several different samples may be collected simultaneously from any given depth. Water for copper analysis, partitioning experiments, and wet sieving will be collected and stored immediately for shipment to the laboratory. Water for PCB analysis, total suspended solids (TSS) and particulate organic carbon (POC) will be filtered and, in the case of PCB analysis, stored in glass carbuoys for laboratory processing.

Several precautionary measures will be taken to guard against PCB and trace metal contamination of samples from either inherent system contamination or interstation contamination caused by a "memory effect" of the pump and teflon tubing. First, all water samples collected during a particular survey will be collected starting with those expected to be least contaminated and finishing with those of highest expected contamination. Second, upon arriving at a particular station, the pump will be placed at the desired depth (starting with surface water) and the system will be flushed with site water for 1/2 hour before the collection of any samples. Tests have shown that this period of flushing is sufficient to remove the "memory effect" from similar systems (Dominic DiToro, personal communication). Further, a portion of the QC program will address this issue (Section 4.3).

3.2.2.3 Biological Sampling. The species of marine animals to be collected for chemical analysis are listed in Table 3.2.6. Most collections will be performed from the RV Mya. Lobsters are difficult to collect in quantity except by lobster traps (Cole et al., 1977). Therefore, it may be necessary to hire a local lobsterman to assist in collecting lobsters. A member of the Battelle sampling team would accompany the fisherman to assure that samples were collected from the right areas.

Since all specimens will be analyzed for PCBs and copper, protocols will be established to assure that the samples are not contaminated from shipboard operations. The first line of control is maintenance of clean equipment and sam .ing gear. The otter trawl net will be fabricated from virgin polymer material which has not been coated with

TABLE 3.2.5. WATER SAMPLING, IMMEDIATE SHIPBOARD PROCESSING.

Water Sample	Sample Volume (liter)	Depth	Dissolved Water Sample Collected	Particulate Sample Collected	Whole Water Sample Collected	Immediate Shipboard Processing
PCB analysis	19 (5 gal.)	surface, bottom	yes	yes	no	Filter water - freeze filter
Copper analysis	1	surface, bottom	no	no	yes	Collect water, refrigerated storage
Total suspended solids	0-1	surface, bottom	no	yes	no	Filter water, record volume
Particulate organic carbon	0-1	surface, bottom	no	yes	no	Filter water, record volume freeze filter
Medium for wet sieving and partitioning experiments	4	bottom	no	no	yes	Collect water, refrigerated storage

TABLE 3.2.6. BIOTA SAMPLES AND COLLECTION METHODS FOR THE FOOD-CHAIN MODEL.

Species	Size Class	Collection Method
Lobster *Homarus americanus*	<75mm; 75-105mm; >105 mm	Lobster Pots
Winter Flounder *Pseudopleuronectes americanus*	<178 mm; 178-254 mm; <254 mm	Otter Trawl
Rock Crab *Cancer irroratus* or Spider Crab *Libinia emarginata*	<20 mm; 20-50 mm	Otter Trawl
Hard-Shell Clam *Mercenaria mercenaria*	<30 mm; 30-60 mm; >60 mm	Rocking Chair Dredge
Mussels *Mytilus edulis*	No Size Classification	Rocking Chair Dredge
Infaunal Polychaete *Nephthys*, *Glycera*)	No Size Classification	Rocking Chair Dredge

any preservative material (e.g., creosote). Before initial deployment of the otter trawl, the gear will be towed behind the RV Mya in an open position to clean the net of any water-soluble contaminants. Prior to all subsequent trawls, the gear will be inspected, all foreign matter removed and finally rinsed thoroughly.

The rocking chair dredge will be constructed of bar steel and steel chain. All foreign matter will be removed and the dredge rinsed with clean seawater before deployment.

Further precautions to be taken during deployment and retrieval of sampling gear consist of insuring that the ship's deck is free of visible signs of contamination. Prior to trawling or dredging operations, the deck will be cleaned with detergent and thoroughly rinsed with seawater. The gear will not be deployed or retrieved through any visible slick on the sea surface. Finally, upon retrieval, the contents of all sampling gear will be placed in a large stainless steel sorting tray which will be kept in a "contaminant-free" condition. Thus, the process of sorting and identification can be made without contaminating the samples.

In each sampling area on each biological sampling trip, every effort will be made to collect a minimum of three replicate specimens of each size class of each species. Sizing will not be performed for the prey species Mytilus edulis and infaunal polychaetes. If extra specimens of a particular size class and species of interest are collected, the extras (up to 10) will be saved and archived frozen for the duration of the project for possible analysis at a later date. Each specimen will be placed in plastic zip-lock bags and frozen on dry ice for return to the laboratory. Before analysis, each specimen will be measured to the nearest millimeter and weighed to the nearest milligram without shell. There is less danger of sample contamination if these measurements are performed under clean laboratory conditions than on board ship.

3.2.3. Shipboard Processing of Samples

3.2.3.1. Sediment. Shipboard processing of sediment samples is simplified by use of the hydraulically-damped gravity corer. Once the coring apparatus is received on deck and initial inspection indicates that the sample has been taken, the corer will be cocked in the safety position, thus removing tension from the core barrel. Maintaining the vertical position of the core barrel throughout all operations and storage, the core barrel will be quickly loosened, dropped below the attachment flange and immediately capped. The barrel will then be carefully moved to a rack needed to maintain the barrel in an upright position for the removal of overlying water. Since the motion of the ship may tend to resuspend the upper microlayer of sediment, the overlying water must be removed immediately. This will be done using a suction appartus, essentially a 1/4-inch teflon "straw" that will be non-contaminating for both copper and PCB. Upon removal of the water, the core will be transferred to a cooler which will maintain the cores at 4°C and in a vertical position until transfer to the laboratory.

3.2.3.2. Water Column Samples. The general shipboard processing requirements of the water sampling field program are presented in Table 3.2.5. In brief, there are two types of samples: those which require onboard filtration, and those which require only the collection and storage of unfiltered water. The former group includes samples for soluble and particulate Cu and PCB, TSS, and POC analysis. The latter includes water for total PCB and copper analysis and water gathered either for the processing of sediments or for partitioning experiments. There will be no on-board processing of water for copper analysis since the possibility of contamination resulting from this procedure is extremely high. All water samples for copper analysis will be processed in the laboratory in a laminar flow hood within 12 hours of collection (see Section 3.2.5).

On the other hand, it is felt that the water samples for PCB analysis can be filtered successfully without contamination problems. Water for PCB analysis will be filtered through pre-combusted glass fiber filters (142 mm Whatman GF-C) in a stainless steel filter holder. This will be a redundant system with the two filters arranged in parallel with a switching valve which will allow water to flow through one filter or the other. This will be the most efficient system to keep the filtration a timely procedure; as one filter becomes clogged with particulate matter, the flow will be switched to the other side permitting full flow. Particulate PCB sample filters will be stored in combusted aluminum foil envelopes and kept frozen until transfer to the laboratory. A section of the QC program will address the onboard processing of water samples for PCB analysis (Section 3.5.4).

TSS and POC samples will be collected on filters (Nucleopore 3μm and combusted Whatman GF-C, respectively). Sample size will be determined by the amount of water which will pass through the filter until it clogs. The filters will be stored frozen until transfer to the laboratory. A separate Nucleopore filter will be placed beneath each filter used for TSS analysis to serve as a salt blank. This filter will be processed identically to the TSS filter.

3.3 LABORATORY K_D DETERMINATIONS AND PARTICLE SIZE FRACTION VERIFICATION

3.3.1 Objectives

The purpose of these laboratory determinations is twofold:

1. To quantify the site-specific modeling parameters relevant to both the transport and food-chain modeling efforts. These parameters include--notably the desorption PCB and metal partitioning constants as well as the adsorption constants.

2. To provide an experimental linkage whereby the water column suspended particulate matter (SPM) measurements for PCB and metals, acquired for a total SPM, can be related to actual particle-size distributions in the water column.

The analysis framework to be used in modeling is based upon the analysis of homologous groups of PCB isomers. Field and experimental data for these groupings is quite scarce in the literature and non-existent for New Bedford Harbor. Second, and perhaps more important, the sediments of the Inner Harbor are so highly contaminated that it is unclear whether the chemical behavior of both PCB and metals is similar to other situations which have been investigated. The model to be constructed for New Bedford Harbor is not to be a screening level calculation for which literature or estimated model coefficients for both PCB and metals are sufficient, but rather a detailed site-specific simulation of the consequences of remedial actions. Therefore, a higher level of confidence in the calculations is required and this implies that chemical as well as the physical parameters related to hydrodynamic and sediment and to food-chain modeling transport be evaluated. It would be inconsistent to focus a large effort on the physical portion of the analysis and use estimates or literature values for the chemical dynamics.

There are three principal chemical reactions that are critical to determining the fate of metals and PCBs; adsorption and desorption reactions that control the distribution of chemical between the particulate and dissolved phases in the water column and in the sediment column; and the reactions that control the fluxes at the two interfaces; the sediment-water and air-water interface. For the sediment-water interface, chemical can be transported to the water column via particle exchange (resuspension) and also via diffusive exchange of the sediment interstitial water. The former is controlled by the rate of resuspension of sediment, the extent of release of PCB and metals from pore waters and the extent of PCB desorption in the water column. The latter is controlled by the interstitial water PCB concentration and the diffusion coefficient within the sediment. This mechanism provides a source of PCB to the overlying water column during non-storm events. Once introduced in the water column, the transport and fate-deposition and biotal uptake are greatly influenced by adsorption of PCB and metals by ambient SPM loadings. The mechanism that controls the flux at the air-water interface is referred to as volatilization which provides an exit route to the atmosphere. These four physical-chemical reactions may be important and must be quantified for New Bedford Harbor sediments and overlying water. We make the assumption here that of the four processes--desorption, sorption, volatilization and diffusion, the first two will largely determine the behavior of PCB and metals. Laboratory studies must be undertaken to examine desorption and sorption, while diffusion will be assessed via direct pore water measurements of PCB and metals in surface sediments combined with pore water measurements of a limited number of 50 cm long cores as part of the field sampling-laboratory analytical program.

3.3.2 Desorption Experiments

A principal source of PCBs to the overlying water is from desorption of sediment-bound chemicals and turbulent release of interstitial chemicals during resuspension that occurs either over the tidal cycle or during storm events. The experiment that directly simulates this process is a consecutive desorption procedure.

The experimental procedure is as follows: A sample of sediment is suspended at various solids concentrations into sea water and agitated for a specific length of time. The particles are separated by centrifugation and the PCB homologous group concentrations and metal (Cu) are measured in the aqueous phase. The contaminated aqueous phase is removed (saved for the sorption studies) and replaced with uncontaminated sea water. The procedure is then repeated for a number of cycles. An analysis of these data provides the partition ceofficient for the desorbable PCB fractions and their dependency on extent of sediment contamination, particle concentration, and desorption time. No such experiments of this type have been focusing on specific isomer groupings or homologous series of PCB isomers. Furthermore, no such experiments have been conducted with natural contaminated sediments. Farrington (personal communication) has found that desorption and sorption as reflected in partitioning of individual isomers (1) varies considerably for the different isomers, and (2) is not a simple function of absolute concentrations of PCB on the solid phase. He found that PCB partitioning between sediments and pore waters varies considerably from site to site and may be a function of dissolved organic matter in the pore water and in the resuspended aqueous phase. Therefore, we plan to conduct these experiments on a number of sediment samples from several locations in the harbor and from in the nearby adjacent receiving water (adjacent to the Cornell-Dubalier site and adjacent to the sewage outfall site (5 in total).

It is expected that such experiments would be conducted in order to quantify the extent of desorption and the similarity of these results to that expected from available laboratory investigations. It is recommended that three sediment samples be obtained from the Acushnet Estuary - New Bedford Harbor area representing a range of contamination. For each sample, the consecutive desorption experiment is conducted with three solids concentrations (10, 1 g/l and 100 mg/l for five cycles (i.e. five aqueous phase replacements). In each case, the dissolved concentration is measured at the end of each cycle and the residual particulate concentration at the end of the third and fifth cycle. Thus, approximately 21 measurements are performed for each sediment sample replicate including initial contaminant concentration (see Table Table 3.3.1). Each cycle should be of sufficient duration for the desorption process to reach equilibrium which is likely to be some fraction of an hour. This time can be determined by some initial screening experiments. It is anticipated that the consecutive desorption experiments will require approximately 126 measurements of PCB and Cu (see Table 3.3.1).

3.3.3 Sorption Experiments

Once introduced into the water column by normal storm-induced, or remedial action (i.e. dredging), resuspension events, PCBs, and metals are transported in the particulate and dissolved phases. The desorption experiments described above are designed to rigorously describe the release of chemicals from the sorbed and interstitial (pore water) aqueous phases. However, modeling parameters must be evaluated to describe the subsequent sorption of dissolved phase PCB and metals onto SPM material that these chemicals will encounter in the estuary and the adjacent waters.

TABLE 3.3.1. DESORPTION STUDY SAMPLE SUMMARY (for PCB and Cu)

1. Dissolved Phase

3 Sediment Samples x 3 Solids Concentrations x 5 Cycles x 2 Replicates

2. Residual Particulate Phase

3 Sediment Samples x 3 Solids Concentrations x 2 Cycles (3rd & 5th) x 2 Replicates

3. Summary

a. Total Determinations for Each Sediment Replicate =
(1 Sediment x 3 Solids Concentrations x 5 Cycles) = 21

b. Total Determinations =
21 x 2 Replicates x 3 Sediments = 126

The experimental procedure is as follows: The aqueous phase from the first cycle of the desorption experiments is introduced to several (three) concentrations of naturally occurring SPM material, obtained from the desorption study after the final cycle, for each sediment sample. Each aqueous phase is combined with one of three SPM concentraitons (500, 100, 10 mg/l) and the mixtures shaken for several hours until equilibrium is reached (The time to reach equilibrium will be determined from a scaling experiment performed prior to the actual sorption studies wherein a time series will be examined). After shaking the SPM material is centrifuged and the aqueous and particulate phases analyzed for PCB and Cu. All experiments are performed in duplicate.

It is expected that these studies will yield a sufficient amount of data on the K_D or distribution coefficient of PCB and metals on actual site sediments. These data are essential to the assignment of correct K_D values for PCB pseudocomponents (i.e. homologous) and copper for the various sediment/SPM size fractions to be encountered in the New Bedford Harbor/Buzzards Bay system, to the transport and food-chain models. It is anticipated that approximately 72 measurements will be conducted as part of these experiments (Table 3.3.2).

3.3.4 SPM Size Fraction Verifications

The requirements of the transport/geochemical model are such that suspended particulate-chemical associations in the water column must be evaluated for each size fraction in the water column. However, it is not practical to acquire this information on every water column sample taken as part of the field measurements. Therefore, we will assume that since the main source of SPM in the water column is the surface sediment, that the size fraction-chemical associations in the sediments, after resuspension, are equivalent to those in the water column. Therefore, we must link the water column measurements of SPM-chemical associations to those in several representative sediments.

A laboratory experiment is designed by which a sufficient quantity of three representative sediments is resuspended in seawater and allowed to settle, and is subsequently collected, size-fractionated, and analyzed for PCB and Cu to yield information that can be extrapolated to all water column particulate measurements.

These data will not be obtained as part of the sorption studies (see previous section) because both the sorption and desorption studies are scaled-down experiments (500 ml in volume). A series of larger volume (20 liter) analogues of the sorption studies

TABLE 3.3.2. SORPTION STUDY SAMPLE SUMMARY (PCB and Cu)

1. Dissolved (Aqueous Phase) - Initial Aqueous Concentration and Initial SPM Concentration Determined as Part of Desorption Study,

   3 Sediment Samples (i.e. Aqueous Phases from Desorption Studies) x 3 SPM Concentrations x 2 Replicates = 18 Samples

2. Particulate Phase

   3 Sediment Samples (i.e. Residual SPM Phase from Desorption Studies) x 3 SPM Concentrations x 3 Fractions (Sand, Silt, Clay) x 2 Replicates = 54 Samples

will yield twelve additional samples (3 sediments x 4 phases--dissolved, sand, silt, clay)) for analysis which will provide the necessary information.

A summary table for all of these laboratory studies is shown in Table 3.3.3.

3.4 LABORATORY BIOACCUMULATION STUDIES

To model PCB and heavy metal contamination of the New Bedford Harbor biota requires estimates of several parameters associated with these chemicals, including: (1) the equilibrium bioconcentration factor, (2) the rate at which chemical is excreted by the exposed species, and (3) the fraction of ingested chemical which is transferred across the gut wall, i.e., the assimilation efficiency. These parameters have been measured for a number of aquatic species, but insufficient data are available for the species being considered in this project. Therefore, laboratory experiments to generate values for these parameters are proposed.

3.4.1 Assimilation Efficiency of Ingested PCBs and Copper

There are sufficient published data available to establish the range of values for assimilation efficiency of PCBs and copper from food by marine animals. Assimilation efficiencies for carnivores usually are in the range of 60 to 90 percent. Herbivores usually have lower assimilation efficiencies ranging from 20 to 60 percent. Limited data for lobsters indicate assimilation efficiencies for tetrachloro- and hexachloro-biphenyls of 40-75 percent (McLeese et al., 1980). More precise values for local lobsters and winter flounder are needed for the food-chain model.

Separate experiments with several replicates will be performed with lobsters and flounder using methods we have used previously to study food-chain transfer of barium and chromium in these species.

Polychaetes will be placed in large flowing seawater tanks containing a substrate of contaminated Achushnet River surficial sediment. The worms reach equilibrium PCB and metal concentration factors relative to the sediments after about two weeks (Fowler et al., 1978). The worms are recovered from the sediments and rinsed in clean seawater.

TABLE 3.3.3. SUMMARY OF SAMPLE REQUIREMENTS FOR DESORPTION, SORPTION VIA VERIFICATION STUDIES (PCB and Cu)

1. Desorption Studies	126 Samples (90 Dissolved, 36 Particulates)
2. Sorption Studies	72 Samples (18 Dissolved, 54 Particulates)
3. SPM Size Verifications	12 Samples (3 Dissolved, 9 Particulates)
Totals	210 Samples (111 Dissolved, 99 Particulates)

The live worms are then weighed and fed to lobsters and flounder which are contained in separate compartments of large flowing seawater aquaria, one animal per compartment. The lobsters and flounder are not fed for the 24-h period before or after the feeding with contaminated worms, which is sufficient time for gastric evacuation (Huebner and Langton, 1982). Any uneaten food and any fecal material produced are collected. The lobsters and flounder are sacrificed and any unassimilated food remaining in the gut is removed and combined with any uneaten food and feces and weighed. For each experiment, separate samples of site sediment, contaminated food, whole lobster and flounder and combined uneaten-unassimilated food are weighed and frozen separately for chemical analysis. All samples are analyzed for the four PCB pseudocomponents and for total copper. Control lobsters and flounder are treated identically to the experimentals except that they are fed clean worms.

The assimilation efficiency is then computed as the ratio of the mass of chemical in the lobster/flounder to the mass of chemical in the food. The validity of the resulting value is checked by mass balance. The measured mass of chemical in the food should equal the sum of the measured masses of chemical in the lobster/flounder and the unassimilated food.

If four replicates are used, the total number of measurements for each experiment is twelve (prey, unassimilated food, lobster/flounder). For the two species (lobster and flounder), the total number of measurements is twenty-four. One analysis of site sediment brings the total to twenty-five.

3.4.2 Bioconcentration Factor and Excretion Rate

Previous laboratory experiments have shown that excretion rate is variable both between and within species. A general trend of decreasing excretion rate with weight has been observed. Bioconcentration factor for a chemical generally shows no trend with species size; however, significant variability is evident in the available literature data.

These factors make it difficult to extrapolate existing data to the species included in this project. Therefore, it is necessary to determine the bioconcentration factor and assimilation efficiency for all the major species to be modeled: lobster, winter flounder, hard clam, and crab. In addition, the focus across all sizes of lobster and winter flounder requires that changes in the values of excretion rate with weight be quantified.

TABLE 3.4.1. SUMMARY OF NUMBER OF SMAPLES FOR CHEMICAL ANALYSIS GENERATED IN THE Kd AND BIOACCUMULATION STUDIES.

Experiment	Type of Sample	Number
Desorption	Sediments	126
Sorption	Water	18
	Sediment	54
Size Verification	Water	3
	Sediment	9
Assimilation	Biota	24
	Sediment	1
Bioaccumulation/Depuration	Biota	120
	Water	120
	Total	475

The reasons for the need to base the New Bedford program on individual PCB isomers or isomer groups are quite straightforward. Aroclor formulations (e.g., 1242, 1254) are each comprised of a complex mixture of many different compounds (Figure 3.5.1). The physical-chemical properties (i.e. solubility, partitioning and sorption coefficients and bioconcentration factors) of these individual compounds differ significantly. That is to say that the dichlorobiphenyls (Cl_2), trichlorobiphenyls (Cl_3)..., octachlorobiphenyls (Cl_8), as isomer groupings will differ markedly in their partitioning behavior (Table 3.5.1). These differences are blurred when one evaluates PCB distributions on the gross Aroclor basis. These properties are the critical parameters and are used in any transport or food-chain models developed in this program.

Assigning an "average" physical-chemical property value (i.e. solubility, partitioning coefficients, etc.) to an Aroclor formulation and using Aroclor-type data for modeling is not scientifically sound and will yield model results with large uncertainties, results that will probably not agree well with actual field data. This point is brought out dramatically by noting that historical PCB levels in the New Bedford area have been reported as 1254 and 1260, whereas the Aroclors which were heavily used (and dumped) were 1016 and 1242 (Farrington, personal communication). Obviously, there is selective dissolution and transport occuring, phenomena that will not be correctly addressed by modeling Aroclor formulations.

However, the proper use of anlaytical data acquired from water column, sediment, and biota for transport and food-chain modeling efforts does not require that PCBs be analyzed according to individual PCB isomer content. This analysis, although technically feasible, would require the quantification of literally hundreds of components, and would be beyond the scope of this project. Instead, we recommend the grouping of PCB into pseudocomponent groupings (i.e. (Cl_3PCB, Cl_4PCB...Cl_6PCB). Several pieces of data from the New Bedford area demonstrate the validity of this approach (Figures 3.5.2-3.5.4). These data presented as chlorobiphenyl isomer groupings or pseudocomponents (i.e. Cl_3, Cl_4...Cl_8) illustrate that the PCB composition of sediments (and suspended particulates) differ dramatically from those in benthic animals. Furthermore, the filter-feeders (i.e. *Pitar* sp. and *Arctica* sp.) exhibit similar compositions to each other, but a different composition compared to lobsters due mainly to partitioning and food-chain transfer mechanisms of the individual PCB compounds. All of these compositional plots in turn differ very significantly from any of the Aroclor formulations (Figure 3.5.5).

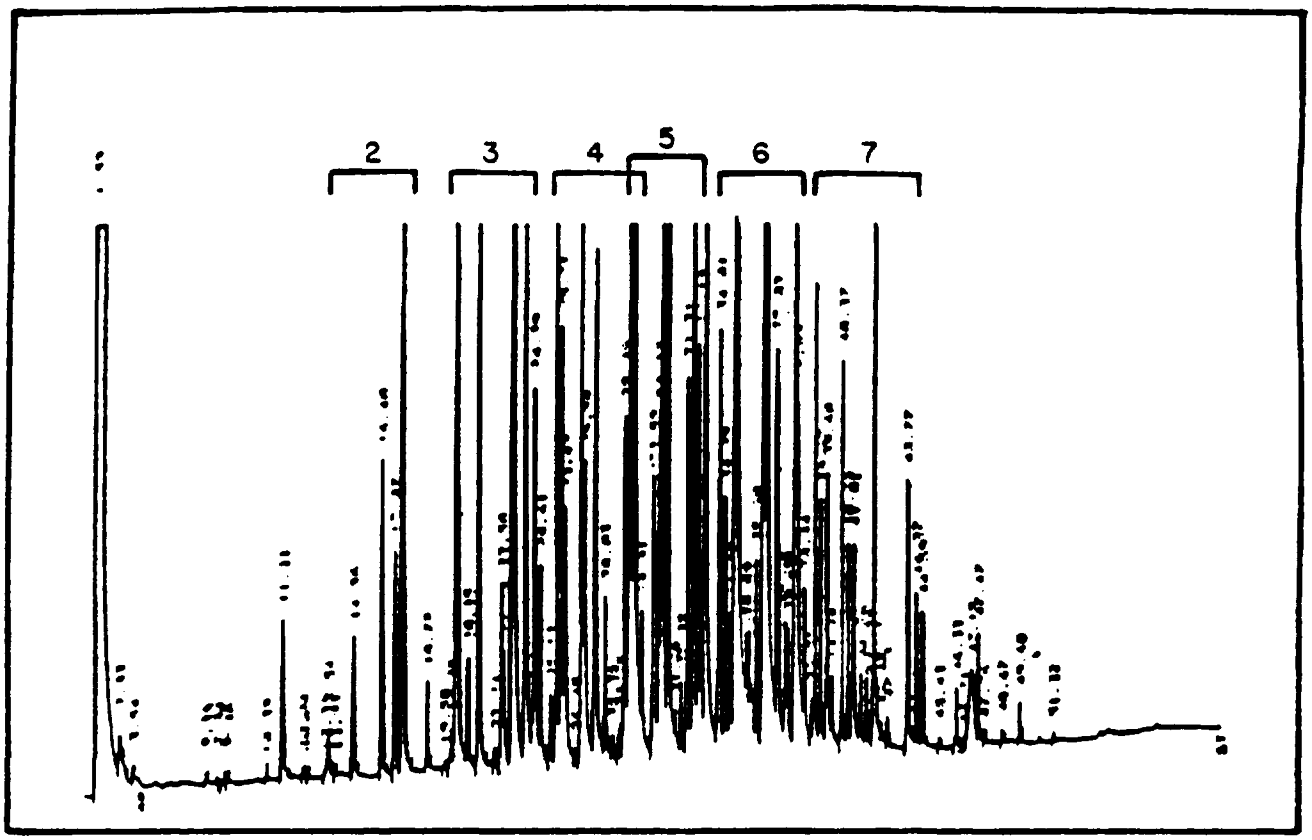


FIGURE 3.5.1. CAPILLARY GC TRACE OF MIXED AROCLOR (1016, 1242, 1254, 1248) STANDARD (NUMBERS REFER TO NUMBER OF CHLORINE ATOMS = PSEUDOCOMPONENT GROUPINGS FOR MODELING PURPOSES).

TABLE 3.5.1. ESTIMATE OF THE DEGREE OF SORPTION OF PCB ISOMERS ONTO COLLOIDAL ORGANIC MATTER OF CONCENTRATIONS 1.0 AND 10 mg ORG C/l USING EMPIRICAL EQUATIONS FROM MEANS ET AL. (1980). SOLUBILITIES ARE ROUGH AVERAGES FROM MCKAY ET AL. (1980). (FARRINGTON UNPUBLISHED).

No. of Chlorine Atoms per PCB Molecule	Solubility (ppb)	K_{OC} (Calculated)	Percent PCB Sorbed (1 mg/liter)	(10 mg/liter)
(Pseudocomponent groupings)				
1	3000	4.77×10^{1}	.475	4.55
2	1000	1.17×10^{4}	1.16	10.5
3	200	4.40×10^{4}	4.21	30.6
4	50	1.37×10^{5}	12.0	57.8
5	10	5.13×10^{5}	33.9	83.7
6	1.0	3.39×10^{6}	77.2	97.1
7	0.5	5.98×10^{6}	85.7	98.4
8	0.2	1.27×10^{7}	92.7	99.2
9	0.1	2.24×10^{7}	96.5	99.6
10	0.016	1.01×10^{8}	99.0	99.9

Note: Solubility and K_{OC} of individual compounds within each pseudocomponent grouping varies.

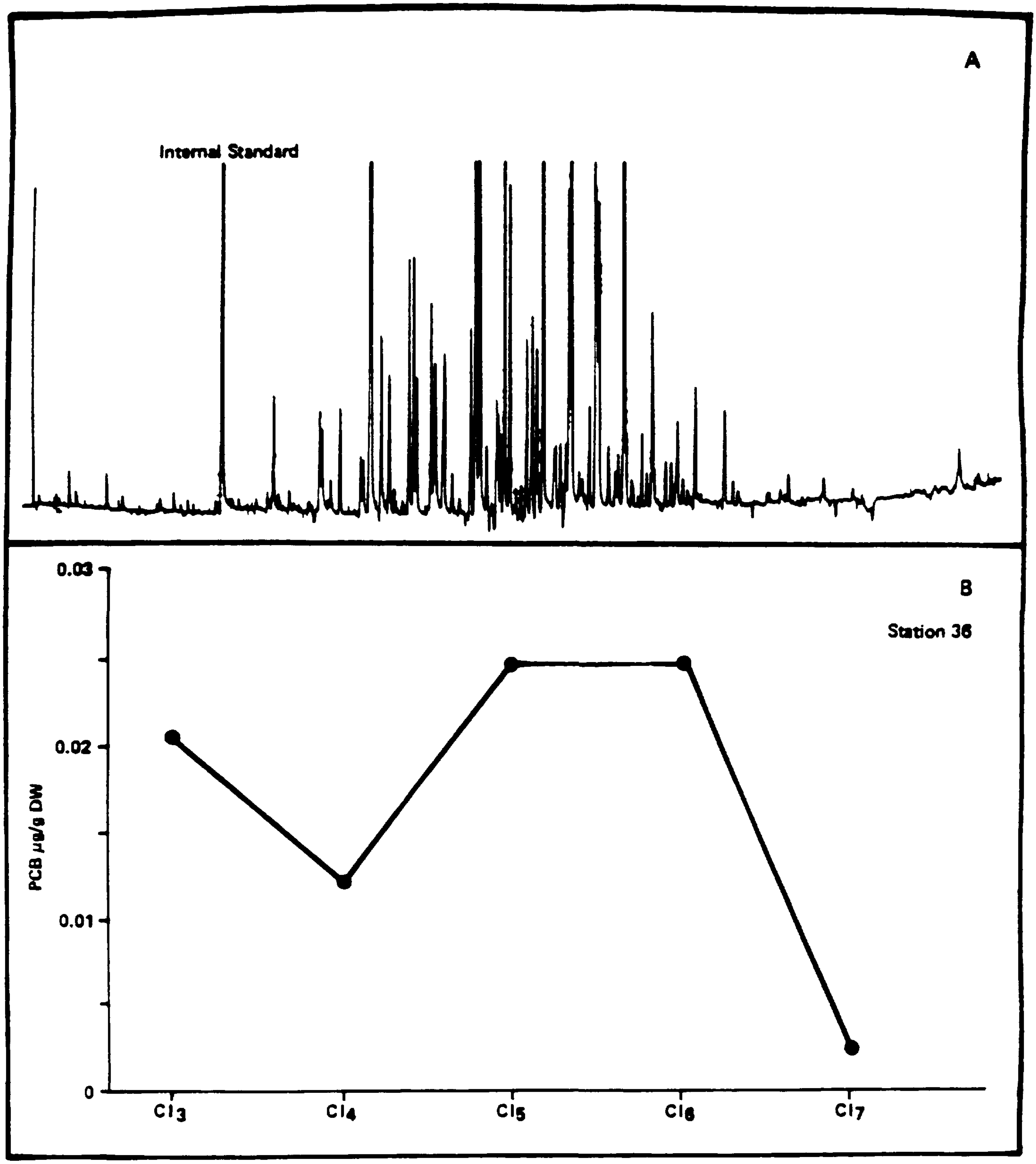


FIGURE 3.5.2. CAPILLARY GC/ECD TRACE (A) AND ISOMERIC COMPOSITION (B) OF TYPICAL BUZZARDS BAY SEDIMENT SAMPLE.

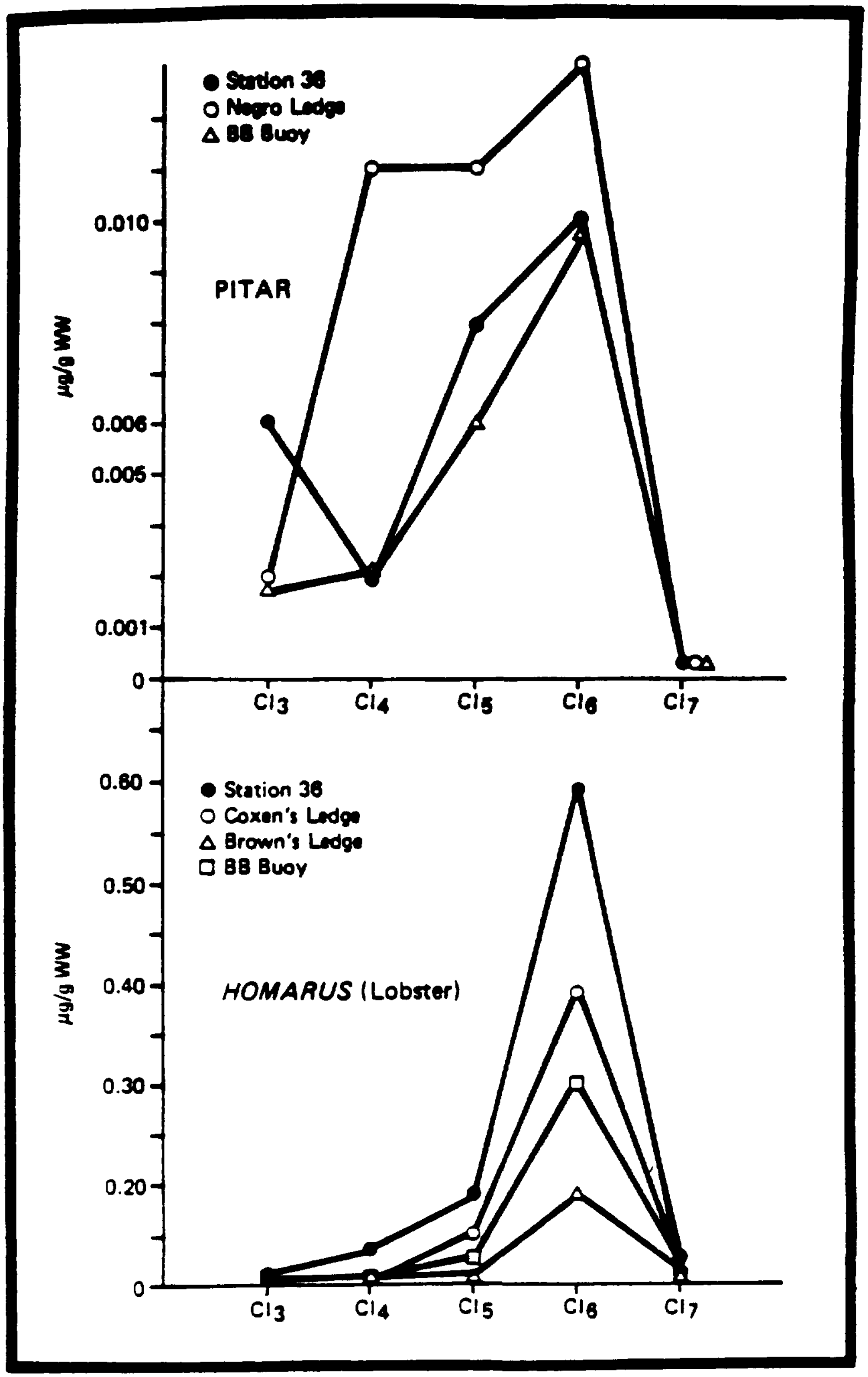


FIGURE 3.5.3. PCB ISOMERIC DISTRIBUTIONS FOR CLAMS (Pitar) AND LOBSTERS (Homarus americanus).

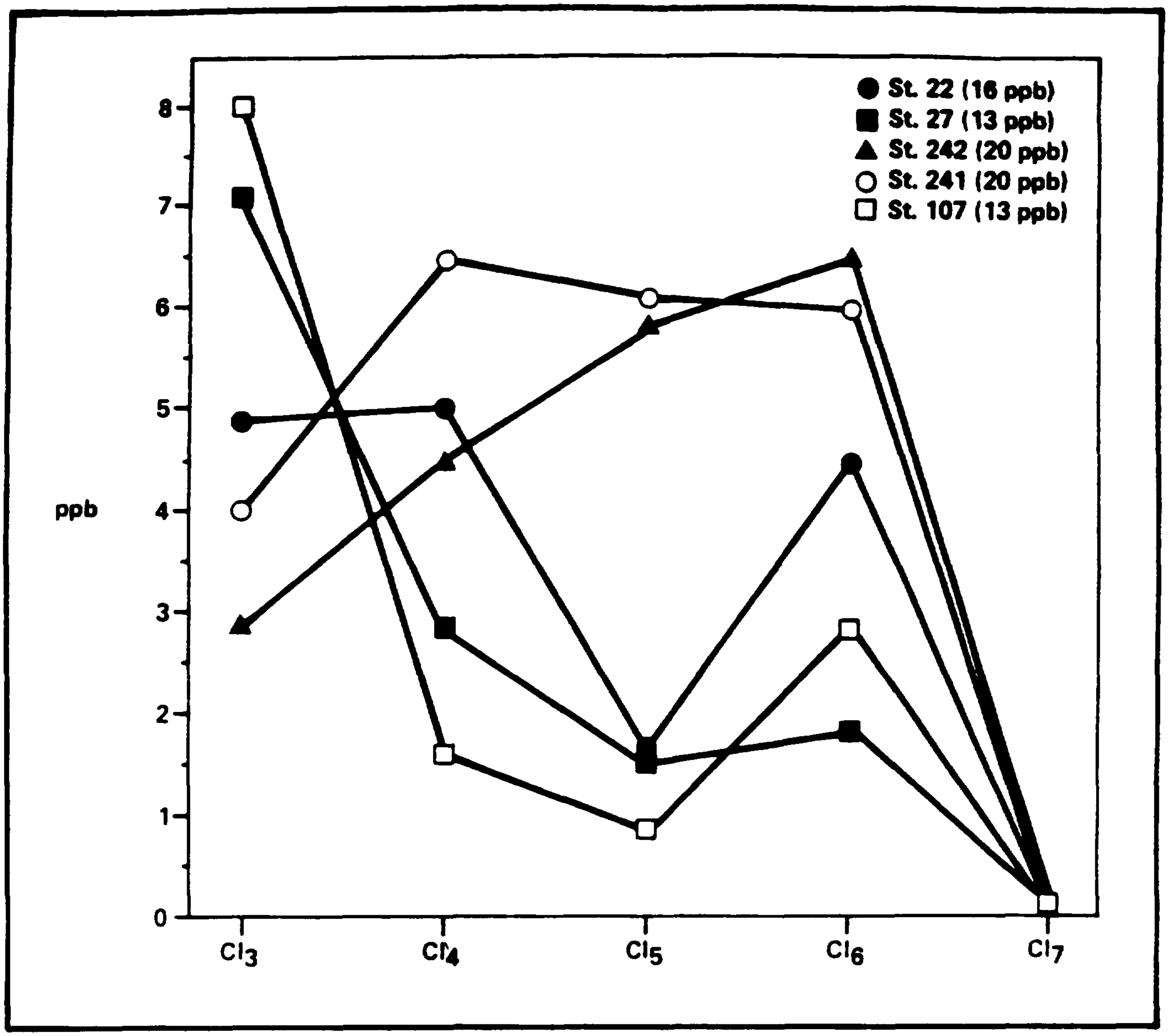


FIGURE 3.5.4. PCB COMPOSITIONAL PLOTS - Arctica islandica; STATIONS 242, 241 FROM BUZZARDS BAY, OTHER STATIONS FROM NEW YORK BIGHT AREA. NOTE COMPOSITIONAL DIFFERENCES BETWEEN AREAS.

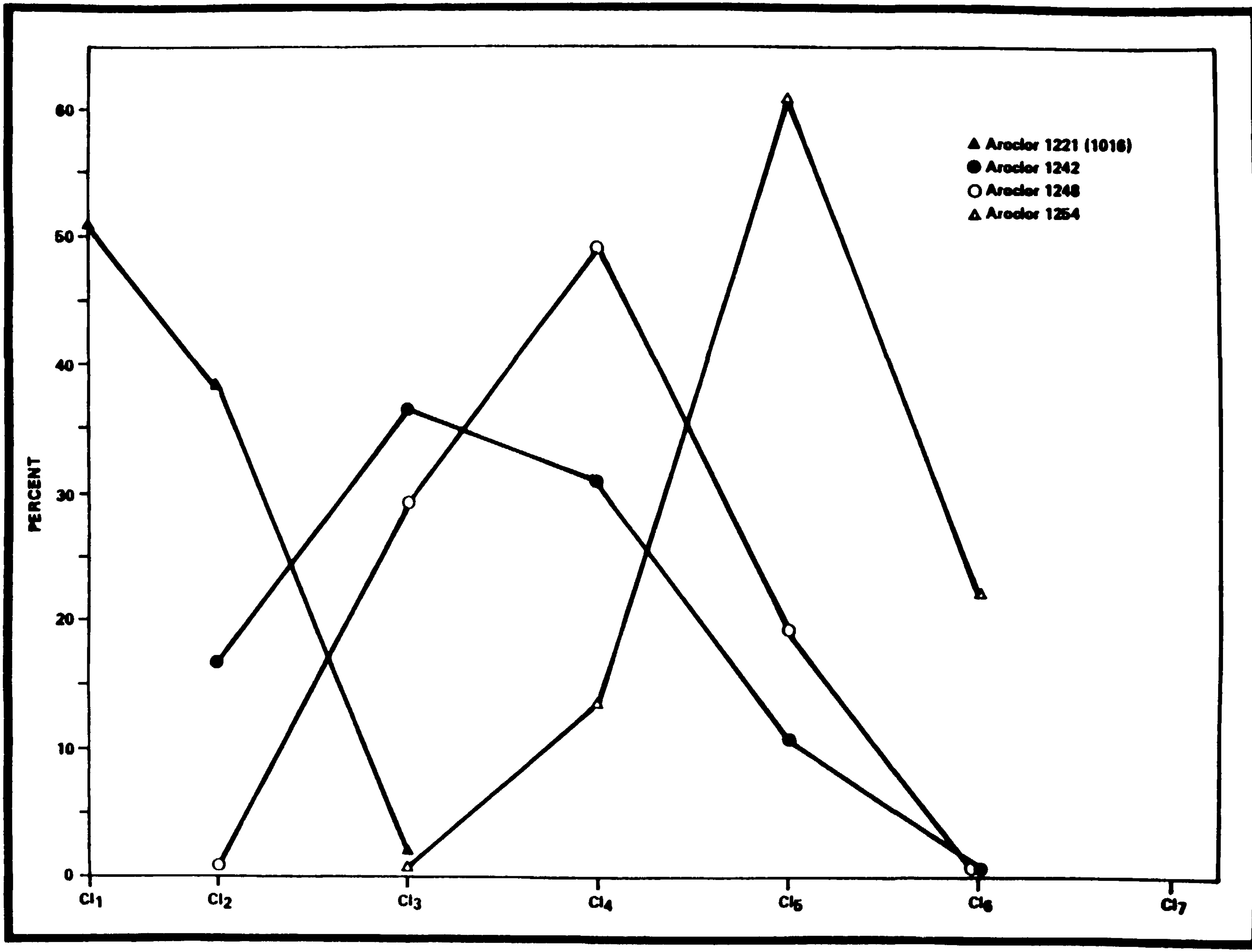


FIGURE 3.5.5. PCB COMPOSITIONAL PLOTS OF SOME COMMON AROCLOR FORMULATIONS

Clearly, the PCB analyses suggested are not the "routine" types of PCB measurements presently being contracted by EPA. Pseudocomponent analysis relies on fused-silica capillary GC/ECD rather than packed column GC/ECD, and a data reduction system capable of discerning and quantifying PCB isomers. The method is straightforward in the hands of careful scientists and the analysis is only marginally more expensive than the routine PCB analysis.

3.5.2. Methodology - Technical Requirements

Table 3.5.2 presents the laboratory analytical requirements of the field survey and laboratory experiments. With the exception of the need to identify and quantify PCB by pseudocomponent groupings, the analytical methods specified are standard EPA or EPA/CE test methods. Analysis of copper in water samples or HF-HNO_3 -HCl digestates will be performed by direct aspiration atomic absorption (EPA Method 220.1). If copper levels are below detection limit with this method, then samples will be reanalyzed by the furnace technique (EPA Method 220.2), or samples concentrated by chelation-extraction (EPA/CE, Procedures for Water Samples, Method 4). Extraction and workup of sediment, particulate, and biota samples for PCB will be by EPA Method 8.85 (Soxhlet Procedure) or Method 8.86 (Sonication Method) followed by standard florisil cleanup. Extraction and workup of water samples for PCB will be liquid extraction (EPA Method 608). Table 3.5.3 presents reporting units and limits of detection based on the requirements of the models and on expected environmental levels of these pollutant components. Since the minimum sample size in many cases may be quite low (for example, pore water, sediment size fractions), the contractor may have difficulty meeting these detection limits. However, careful laboratory practice must insure that a number is generated for each environmental sample analysis and that no result is "below detection limits". The PCB pseudocomponents which will be quantified in all survey samples will be Cl_3, Cl_4, Cl_5 and Cl_6PCB. This data set represents a compromise between the real needs of the modelers for all PCB pseudocomponent information and the budgetary constraints placed on the study.

Since the analysis of PCB by pseudocomponent groupings is "non-standard" with regards to EPA methodology, this procedure is specified as follows:

TABLE 3.5.2. LABORATORY ANALYTICAL METHODS

Analysis	Sample Description	Analytical Methods
PCB in Water Samples		
Particulate	142 mm glass fiber filter	-EPA Method 8.85 or 8.86, followed by Method 8.08, modified for high resolution capillary gas chromatography (HRCGC) and pseudocomponent analysis
Dissolved	2 L dichloromethane extract (wet)	-EPA Method 608, modified for HRCGC and pseudocomponent analysis
Pore Water	10-100 ml seawater (filtered)	-EPA Method 608, modified for HRCGC and pseudocomponent analysis
PCB in Sediment Samples		
Gross Sediment	10-100 g sediment (wet)	-EPA Method 8.85 or 8.86, followed by Method 8.08, modified for HRCGC and pseudocomponent analysis
Sediment Size Fractions	1-100 g sediment (wet)	-EPA Method 8.85 or 8.86, followed by Method 8.08, modified for HRCGC and pseudocomponent analysis
PCB, Biota	10 g-5 kg (wet)	-EPA Method 8.85 or 8.86, followed by Method 9.01 and Method 8.08 mofified for HRCGC and pseudocomponent analysis
Copper in Water Samples		
Particulate	47 mm Nuclepore filter	-EPA/CE-81-1 Procedure for Sediment Samples, Method 1
Dissolved	1 L seawater (filtered, acidified)	-EPA/CE-81-1 Procedure for Water Samples, Method 4
Pore Water	10-100 ml seawater (filtered, acidified)	-EPA/CE-81-1 Procedure for Water Samples, Method 4
Copper in Sediment Samples		
Gross Sediment	10-100 g (wet)	-EPA/CE-81-1 Procedure for Sediment Samples, Method 1
Sediment Size Fractions	1-100 g (wet)	-EPA/CE-81-1 Procedure for Sediment Samples, Method 1
Copper, Biota	10 g-5 kg (wet)	-EPA/CE-81-1 Procedure for Sediment Samples, Method 1 digestate analyzed by graphite furnace, EPA Method 220.2
Sediment Grain Size	3 g (wet)	-Sieve, pipette (Folk, 1954)
Sediment Total Organic Carbon	3 g (wet)	-EPA Method 415.1
Particulate Organic Carbon	142 mm glass fiber filter	-EPA Method 415.1

TABLE 3.5.3. LABORATORY ANALYTICAL LIMITS OF DETECTION AND REPORTING UNITS

Component (or Pseudocomponent)	Water Sample Dissolved Fraction; Pore Water (10^{-9}g/kg)	Water Sample Particulate Fraction; (10^{-9}g/g)	Biota (10^{-9}g/g)
Cl_3PCB	0.2	0.05	.05
Cl_4PCB	0.2	0.05	.05
Cl_5PCB	0.2	0.05	.05
Cl_6PCB	0.2	0.05	.05
Copper	100	3,000	100

(Note: PCB pseudocomponent quantification refers only to the gas chromatographic analysis and the subsequent method of data reduction. Sample extraction procedures and cleanup are the same as specified by standard EPA methods (Table 3.5.2).

Gas Chromatographic Analysis

All gas chromatographic analyses will be performed in the splitless mode. Specified gas chromatographic column will be fused silica 0.25 mm I.D. x 30 m minimum length. Stationery phase will be SE54 (non-bonded) or DB-5 (bonded). Detection will be with halogen specific detector (electron capture or electrolytic conductivity). Integration should be with microprocessor controlled recording integrator or similar device capable of automatically computing peak areas using baseline correction.

Gas chromatographic conditions:

PCB, Pesticide Analysis

Initial Temperature	120°C	Injector Temperature 275°C
Initial Hold	0.10 min	Detector Temperature 325°C
Program Rate	2°C/min	
Final Temperature	290°C	
Final Hold	60 min	

Data Reduction

Amounts of compounds of interest are computed by the ratio of individual peak areas to the area of an internal standard, according to the formula:

$$Q_{Sample} = \frac{A_{Sample}}{A_{is}} \times R \times Q_{is}$$

where

Q_{Sample} = amount of pseudocomponent of interest

A_{Sample} = sum of integration areas of individual isomers comprising pseudocomponent

A_{is} = integration area of internal standard

R = response factor = $\dfrac{A_{is}/\text{unit concentration}}{A_{Sample}/\text{unit concentration}}$

R is determined by separate analysis of standard solutions of reference compounds (see below).

Q_{is} = amount of internal standard added to sample.

Each pseudocomponent will be comprised of a minimum of five individual isomers correctly identified as members of that grouping by GC/MS analysis (Figure 3.5.1) under GC conditions identical to above standard conditions.

Response factors for each pseudocomponent will be the average of a minimum of five individual isomers (calibration standards) within each chlorine grouping. Commercially available pure isomers will be used for this purpose. Recommended internal standards include 3,4,5-tribromobiphenyl and tetrachloronitrobenzene.

Data Storage and Transfer

Due to the critical importance of the PCB pseudocomponent data and the possibility that raw analytical data may be misinterpreted by the contract lab and, therefore, misquantified, all raw chromatographic data (analog or digital waveform data), reduced data (retention time, peak area), and support data (sample I.D., wet weight, dry weight, lipid weight, amount of internal standard) must be stored on magnetic medium (industry standard tape) and be available on a continuing basis to the scrutiny of Battelle personnel. Battelle will then input these data in the project data base and utilize these data in the development of models.

3.5.3. Immediate Laboratory Processing

All field samples returning to the laboratory will require varying degrees of immediate processing (Table 3.5.4). All organisms, and particulate matter collected in the field for PCB, TSS, and POC analysis will require only freezer storage. However, other samples will require either extraction or filtration (Figures 3.5.6-3.5.9). All sediment cores will require extrusion and subsampling for grain size analysis and total organic carbon. However, depending on the type of sediment sample, other processing must occur immediately. The processing of sediment samples requiring pore water analysis is complicated by the necessity to keep the sample in an oxygen-free environment until the pore water is collected and split into copper and PCB subsamples. These sediments, which would normally be worked up in a laminar flow hood will be processed in a glove box under nitrogen.

It cannot be over-emphasized that sediment cores (profile, compartment analysis) and water samples for copper analysis must be processed within twelve hours of collection. The experience of years of environmental research has shown that these samples should in reality be processed immediately onboard ship. However, this work

TABLE 3.5.4. IMMEDIATE LABORATORY PROCESSING OF FIELD SAMPLES

	Sample	Processing Required
Sediment	Compartment Differentiation	Extrusion, centrifugation, sieving, filtration, sample splitting, storage
	Gross Characterization	Extrusion, sample splitting, storage
	Depth Profile	Extrusion, centrifugation, filtration, sample splitting, storage
Water	Copper Analysis	Filtration, freezer storage
	Dissolved PCB Analysis	Extraction, refrigerated storage
	Partition Experiments, Sieving	Refrigerated storage
Filters	Particulate PCBl	Freezer storage
	Total Suspended Solids	Freezer storage
	Particulate organic carbon	Freezer storage
Organisms		Freezer storage

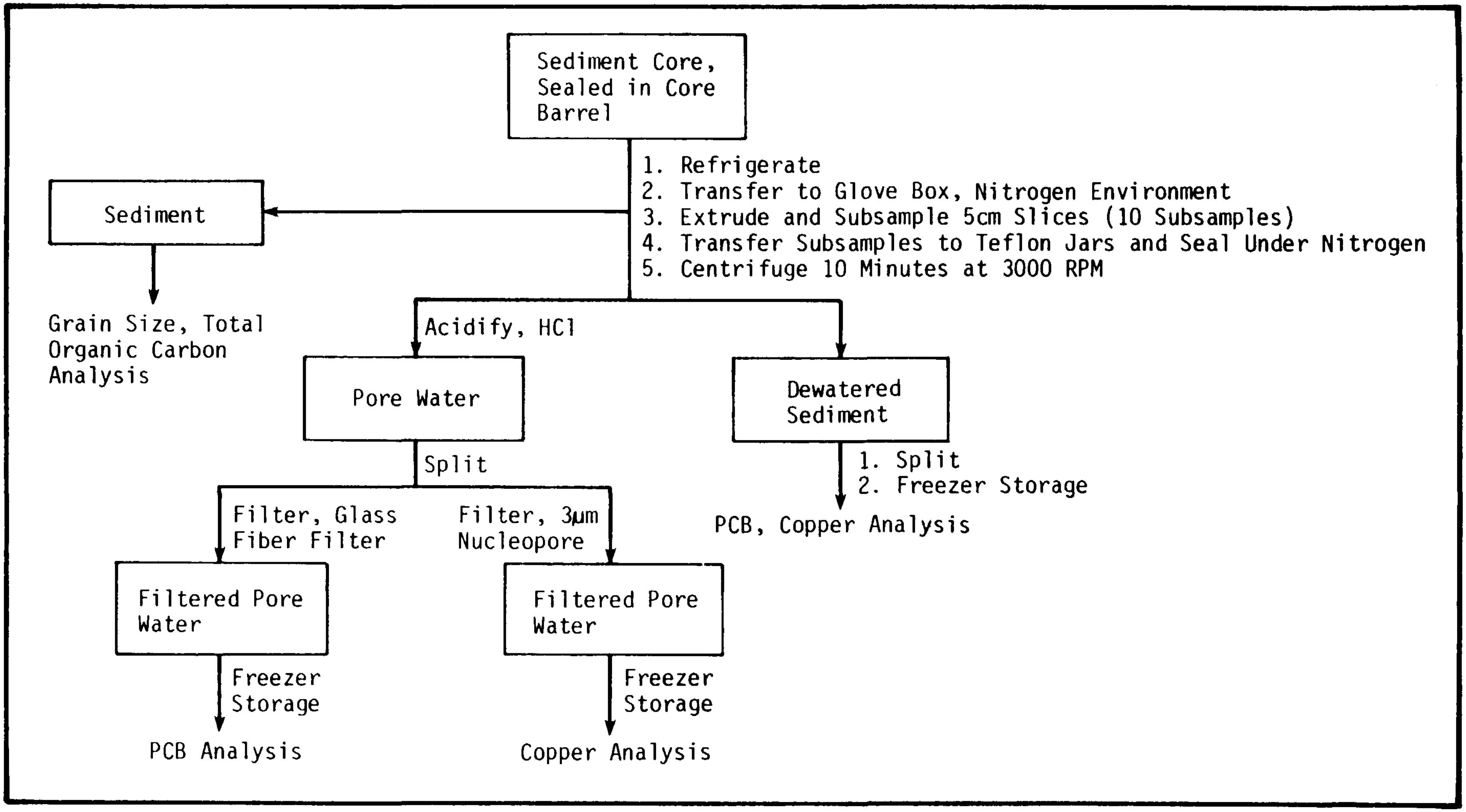


FIGURE 3.5.6. IMMEDIATE LABORATORY PROCESSING OF SEDIMENT SAMPLES, DEPTH PROFILE.

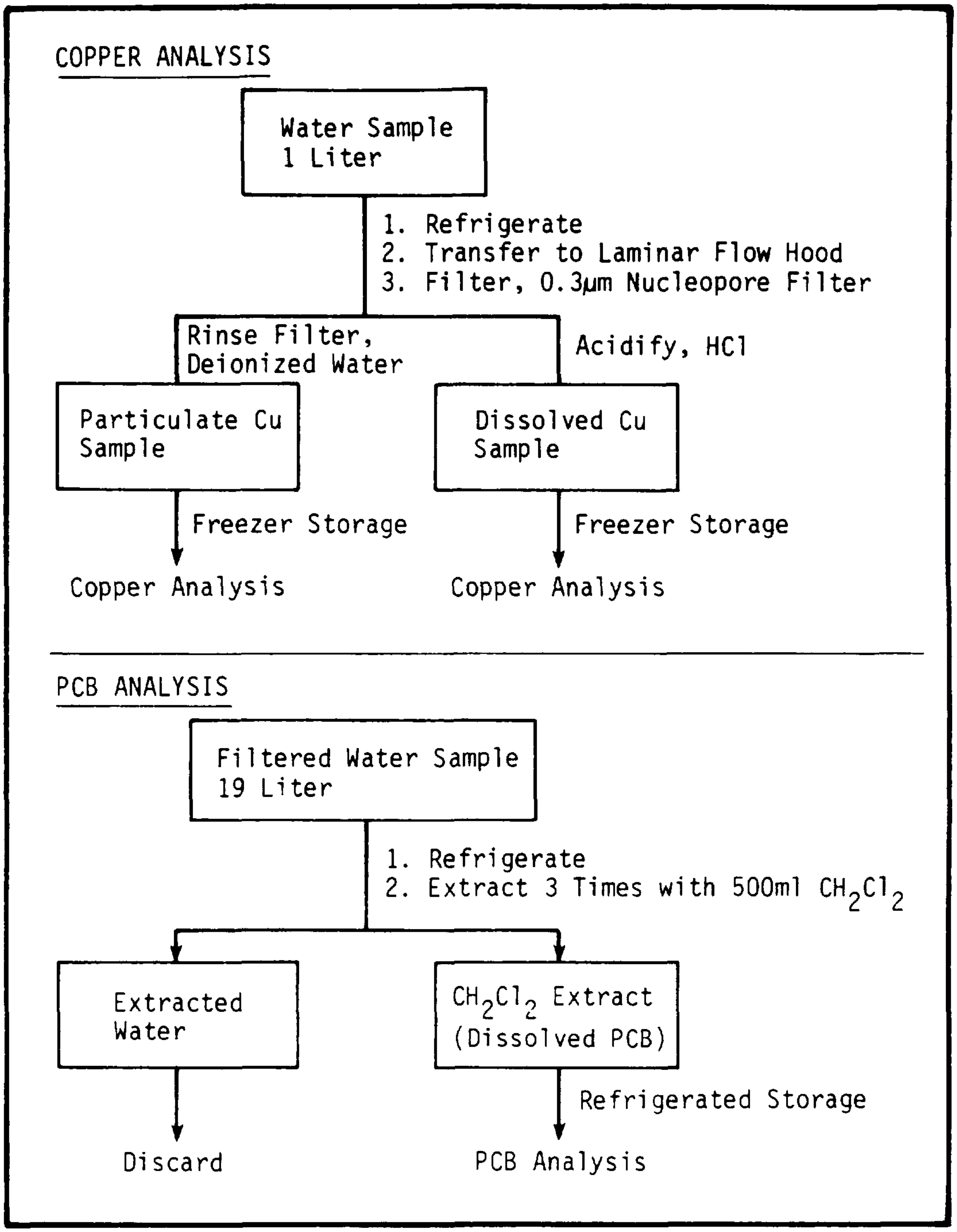


FIGURE 3.5.7. IMMEDIATE PROCESSING OF WATER SAMPLES, COPPER ANALYSIS.

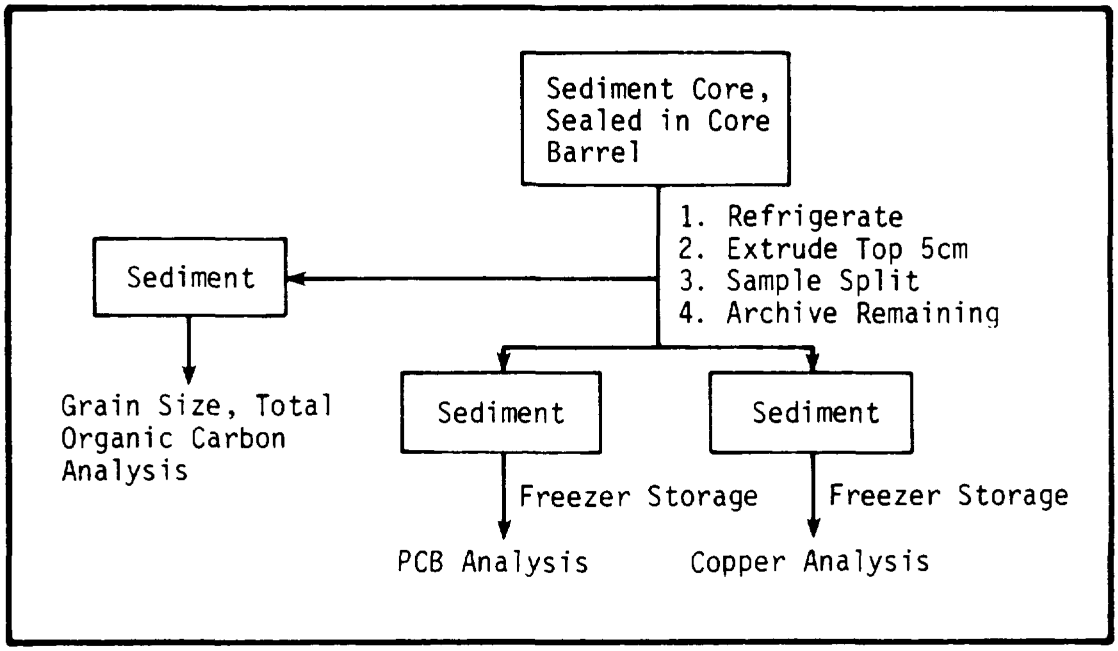


FIGURE 3.5.8. IMMEDIATE LABORATORY PROCESSING OF SEDIMENT SAMPLES, SURFACE SEDIMENT, CHEMICAL CHARACTERIZATION OF GROSS SEDIMENT.

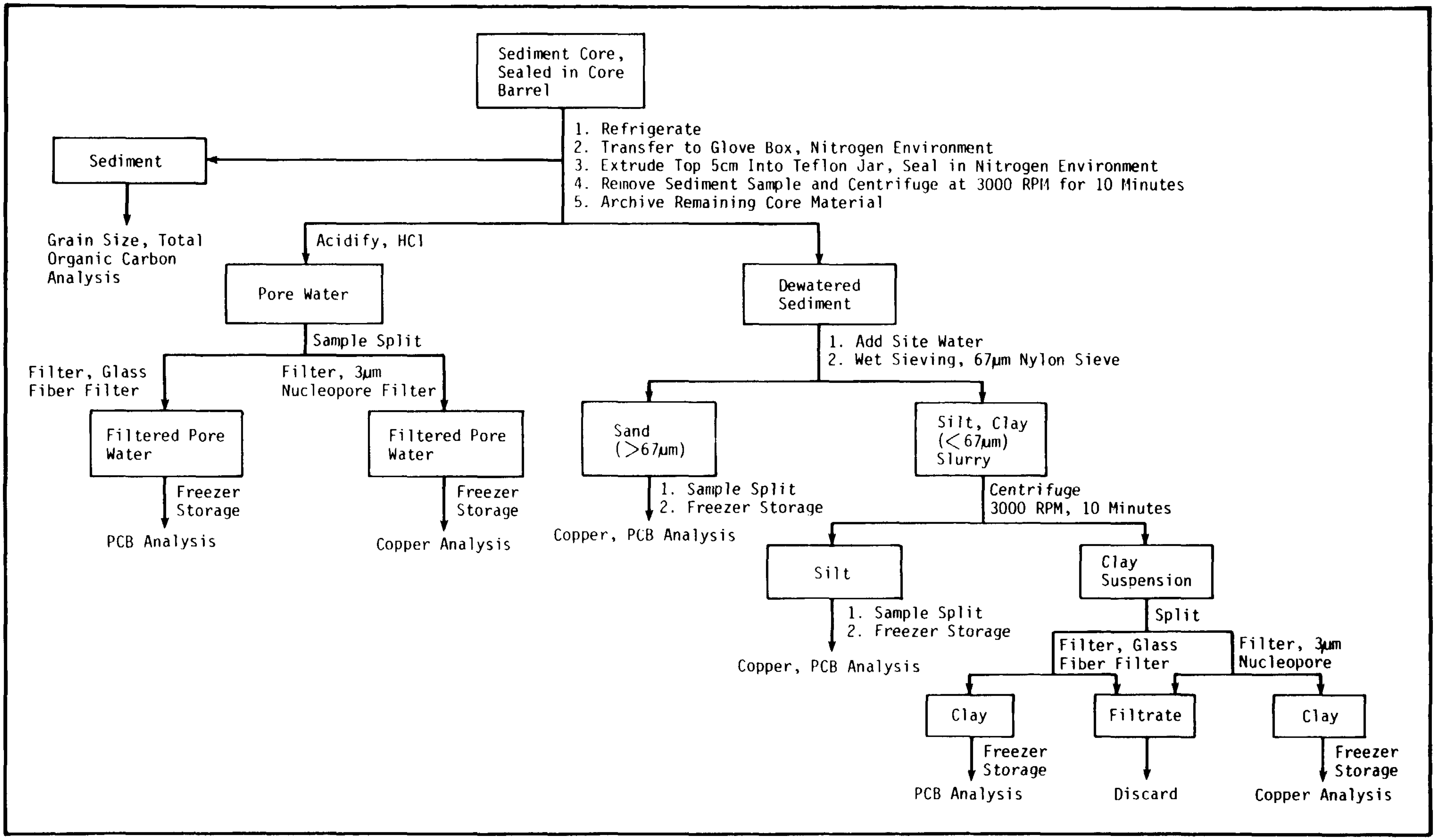


FIGURE 3.5.9. IMMEDIATE LABORATORY PROCESSING OF SEDIMENT SAMPLES, SURFACE SEDIMENT COMPARTMENT DIFFERENTIATION.

Single experiments will be performed for each of the species. For lobster and winter flounder, juvenile and adult inviduals will be studied separately. Ten individuals will be placed in each flow-through exposure tank. They will be exposed to a constant concentration of chemical for a period of 30 days. At this time, they will be transferred to clean water for an additional 30 days. Individuals will be removed from the tank at the following times, in days 0, 2, 5, 10, 20, 30, 35, 40, 50, and 60. These individuals will be weighed and frozen immediately for later analysis of whole body PCB and copper concentration and lipid content.

A total of six exposures will be performed: juvenile lobster, adult lobster, juvenile flounder, adult flounder, hard clam, and crab. Ten measurements are required for each exposure and each chemical. If two replicates are used, the number of measurements per chemical is 120. An equal number of water samples must be analyzed.

The total number of samples generated in the two laboratory studies (Kd determinations and bioavailability) are summarized in Table 3.4.1.

3.5 LABORATORY ANALYTICAL CHEMISTRY PROGRAM

3.5.1. Methodology - General

With the major exception of identification and quantification of PCB pseudocomponents, the analytical methods specified in this program conform to standard EPA or EPA/U.S. Army Corps of Engineers (CE) test methods. And with the major exception of the identification and quantification of PCB pseudocomponents, the analytical work can be completed under the EPA Contract Laboratory system. Analytical methods used by contract laboratories determine PCB levels based on closest match to a particular Aroclor, data which is not appropriate to this study and data which can result in inaccurate measurements of PCB in marine samples. For this reason, we require that PCB be quantified by isomer grouping type. The PCBs may have been selectively weathered and metabolized or otherwise partitioned during transport and uptake. A number of recent scientific publications (e.g., Duinker et al., 1980, 1983; Duinker and Hillebrand, 1983; Ballschmitter and Zell, 1980; Albro et al., 1977; Zell and Ballschmitter, 1980; Boehm, 1983) point out the distinct scientific advantages of PCB component or isomer grouping-type analyses in the study of marine environmental transport and fate of PCB.

must also be performed under controlled laboratory conditions, a situation not possible without a much larger ship with clean room and laboratory facilities. An alternative might be to process the samples in a shore-based portable laboratory. However, the cost of such facilities for an extended field survey such as this requires that an alternative solution be reached. The protocol of transferring and processing time-critical samples within 12 hours of collection is a compromise between the needs of collecting valid environmental samples and the budgetary needs of the project.

3.5.4 Quality Control/Quality Assurance

The field sampling and analysis QC program has two parts: the field sampling QC program administered by Battelle and the analytical laboratory QC program administered by a yet unknown laboratory. In many ways, the field sampling QC program (Section 4.3) will serve as a check on the analytical program. For example, duplicates, blanks, and spiked samples will all be sent from the field to be analyzed along with routine environmental samples. However, the field QC program is no substitute for a strong laboratory QC program. The analytical laboratory provides qualitative and quantitative data for use in decision-making. To be valuable, the data must accurately describe the characteristics and concentrations of constituents in the samples submitted to the laboratory. In many cases, because they lead to faulty interpretations, approximate or incorrect results are worse than no result at all.

Because of the importance of laboratory analyses in determining practical courses of action that may be followed, laboratory quality assurance programs to insure the reliability of the field survey data are essential. An established, routine, quality assurance program based on the Handbook for Analytical Quality Control in Water and Wastewater Laboratories (EPA-600/4-79-019) applied to each analytical test and instrumental method is necessary for the determination of measurement quality and overall program validity.

Each analytical method has a rigid protocol specified in this Work Plan. Similarly, QC associated with a test must include definite required steps for monitoring the test and insuring that its results are correct. The steps in QC vary with the type of analysis. In any instrumental method, calibration and checking out of instrumental response are also QC functions. All of the experimental variables that affect the final results should be considered, evaluated, and controlled.

In summary, laboratory data, in quantitative terms, are reported by the analyst. These values will be interpreted by Battelle and EPA to determine what remedial action is necessary in New Bedford Harbor. The analytical QA/QC program must demonstrate that the analytical results are the best possible. Quality assurance programs initiated from, and based upon EPA recommendations should increase confidence in the reliability of the reported analytical results.

3.5.5 Incorporation of the Analytical Program Into the Overall Study

The program management staff, task leaders, and consultants to the program all agree that incorporation of the data generation tasks (i.e. analytical chemistry) into the overall program is highly desirable from both logistical and scientific perspectives. The modeling group efforts are closely linked with the analytical group efforts and strong interactions between these groups are essential. We feel that the quality and timely delivery of the final product (i.e. predictive modeling efforts) will only be as successful as is the timeliness and quality of the data generation phase. Specifically:

1. There is a significant overlap between the field sampling and immediate sample processing requirements for sediment and water samples and the analytical chemistry components, making separation of the analytical tasks quite artificial. This is true for all types of samples, but especially true for Kd and bioaccumulation experiments where the experiments are being done in the laboratory and analytical results are needed to evaluate the experimental design <u>during the experiments</u> to possibly refine the design prior to proceeding further with the experiments.

2. Generation of the analytical data lies on the critical path of the project in terms of project scheduling and quality control. Meeting project deadlines should be the responsibility of the project manager.

3. We anticipate that the modeling team will frequently have to interact with the data generators to clarify analytical findings, time requests, analytical reruns, etc.

4. Significant savings in shipping costs and other laboratory processing costs will be realized by EPA by combining field sampling, initial processing, and analytical chemistry components, together under the direction of the program manager. We estimate that these costs are approximately $35,000.

5. Analytical detection limits and specific techniques required to quantify PCBs, store data by individual isomers and report data as pseudocomponent groupings are not routine requirements for remedial action studies. However, these techniques represent state-of-the-art procedures that are presently being used by Battelle for marine chemical studies and are being developed by Battelle for routine use in EPA programs. Levels of PCBs and metal in many of the samples are very low and would be reported as "non detected" under present EPA contract laboratory procedures and specifications. Such "undetectable data are useless for the modeling program.

We therefore feel that from both logistical and scientific perspectives, Battelle should be allowed total control of the project, including performance of the total analytical program.

3.5.6 Turn-Around Time

Because of the need of the modelers for field and experimental data on a continuing basis and the need of Battelle to review and approve these data, a short turn-around time is required for many of the measured parameters. It can be seen from Table 3.5.5 that near immediate turn-around times are required for the copper and PCB analysis of laboratory Kd samples. This is essential for the timely completion of this project in that results from each experiment may be essential in the design of subsequent experiments. The 30-day turn-around of all other data is necessary for successful completion of this project. In our scheduling plan for the project summarized in the PERT diagram (Figure 4.2.2), we provided an analytical output of 50 samples per week, with real-time delivery of results to users even before the end of the sampling trips.

TABLE 3.5.5. ANALYTICAL CHEMISTRY - TURN-AROUND TIME (MINIMUM REQUIREMENTS)

Analysis	Kd/Fractionation and Bioaccumulation Experiments (Turn-Around Time (Days)	Field Data
Cu, PCB in Water Samples		
Particulate	7	30
Dissolved	7	30
Pore Water	7	30
Cu, PCB in Sediment Samples		
Gross Sediment	-	30
Sediment Size Fractions	7	30
Sediment Size Fractions	7	30
Cu, PCB in Biota	-	30

3.6 HYDRODYNAMIC AND SEDIMENT/CONTAMINANT TRANSPORT MODELING

3.6.1 Introduction

The objectives of this task are to predict the transport, deposition, and resuspension, as well as the fate of PCBs and a heavy metal in the Acushnet River/New Bedford Harbor/Buzzards Bay System under normal and extreme flow conditions (e.g., storms). This information will help determine the effectiveness of remedial actions in reducing the concentrations of PCBs and the heavy metals in the study area.

PCB and heavy metal migration in the Acushnet River/New Bedford Harbor/Buzzards Bay are controlled by the following mechanisms:

- transport resulting from

  - water movement
  - sediment movement
  - bioturbation

- intermedia transfer resulting from

  - adsorption/desorption
  - precipitation/dissolution, where applicable
  - volatilization (for PCBs)

- degradation resulting from

  - chemical degradation
  - biological degradation.

To predict the migration and fate of the PCBs and heavy metals in the study area, all these complex and interacting mechanisms must be integrated into a single system. Mathematical models, coordinated with field and laboratory measurements are the most effective way to integrate these mechanisms into a single system. The mathematical model chosen for the study must include these mechanisms explicitly to predict the transport and fate of PCBs and heavy metals in the hydrologic system; this is especially true if the model will be used to evaluate the effectiveness of various remedial action alternatives.

Review of the Buzzards Bay/New Bedford Harbor/Acushnet River estuary system indicates that the major hydrodynamic characteristics are driven by winds and tide. Because the movement of the water mass is associated primarily with winds and tidal action, the influence of these features must be simulated in some detail. For instance, tides must be simulated through the daily cycle because, in the absence of winds, tides are the only major causes of water, sediment, and contaminant transport. It is important to note that in the Acushnet River and the inner New Bedford Harbor, the net flow near the contami nated bed is toward the land, while the net flow near the water surface is seaward. Winds are expected to induce major circulation patterns in the surface water and, therefore, a variety of wind conditions must be considered including major storms, which significantly affect the resuspension of sedi ments. Circulation induced by wind have three-dimensional velocity distri butions, which could possibly produce counter flows near the seabed.

Thus, to accurately simulate these flow fields, an unsteady, three-dimensional hydrodynamic model must be used. Solar heating during the summer and early fall leads to a degree of stratification affecting flow patterns in the study area, especially in the shallows of the northern and western regions of the system. Spatial variations of salinity are small, and this effect could probably be eliminated from the standpoint of hydrodynamic analysis.

Transport of sediments in the system is controlled by flows affected by winds and tides, as well as by wind-induced waves that occur under normal and storm conditions. The sediments in the study area vary from coarse sand to fine clay and organic matter. Because sediment migration (transport, deposi tion, and resuspension) and contaminant adsorption/desorption vary signifi cantly with sediment sizes (e.g., sand, silt, and clay) and types (e.g., inorganic and organic materials), sediments of different sizes and types must be evaluated separately to determine their migration and adsorption/desorption in the study area. In addition, because PCBs and heavy metals exist in both dissolved and particulate (sediment-sorbed) phases, the models must consider the interactions of PCBs and heavy metals with water and sediments (of both suspended and bed sediments).

Thus, to simulate the hydrodynamics and transport of energy/mass (e.g., water temperature, salinity, sediments, PCBs, and a heavy metal) in the Acushnet River/New Bedford Harbor/Buzzards Bay system, an unsteady, three-dimensional, numerical model must be used to address all of these important physical/chemical/biological phenomena that impact the transport process.

As indicated by various review studies (Hoffman et al. 1978; Onishi et al. 1981; Boutwell and Roberts 1983), the existing time-dependent, three-dimensional code, TEMPEST/FLESCOT (Onishi and Trent 1982; Trent et al. 1983) has the basic capabilities and features needed for this study. Note that a brief description of the review and selection of the model is provided in Appendix A.

TEMPEST/FLESCOT solves for the following:

- hydrodynamics
- water temperature distribution
- salinity distributions
- turbulence
- sediment transport for three sediment size fractions
- dissolved contaminant transport
- particulate (sediment-sorbed) contaminant transport for three size fractions.

The TEMPEST/FLESCOT code will be modified slightly and used to predict the transport, distribution, and fate of the PCBs and a heavy metal within the study area. The modeling will be coordinated with field and laboratory measurements, which will be conducted by Battelle, New England Marine Research Laboratory and Wood Hole Oceanographic Institute. Predicted distribution of PCBs and a heavy metal in the water column and in the seabed will be supplied to HydroQual Inc., as input for their food chain modeling to determine PCB and heavy metal accumulations in selected aquatic biota.

3.6.2 Overview of Modeling Task

To achieve these objectives, the modeling effort will be divided (Figure 3.6.1) into the following five subtasks:

1. review and evaluation of existing data
2. modification of the model
3. field sampling support and data analysis

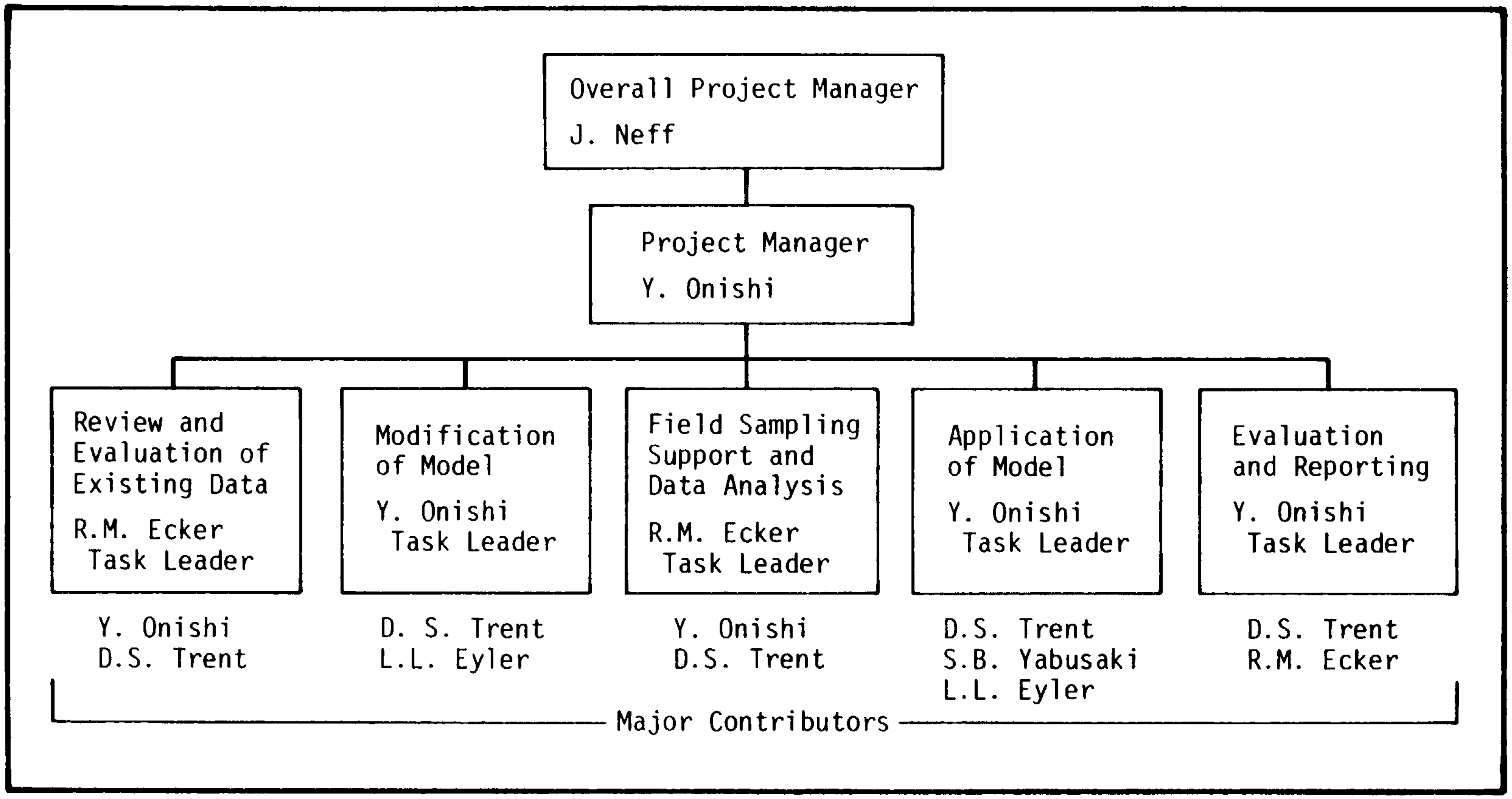


FIGURE 3.6.1. ORGANIZATION OF THE PHYSICAL/CHEMICAL MODELING TASK

4. application of the model
5. evaluation and reporting.

The following is a brief description of these subtasks:

3.6.2.1. Review and Evaluation of Existing Data. Available information on flows, tides, waves, wind, water temperature, salinity, sediment, PCBs, and a heavy metal in the study area will be compiled, reviewed, and evaluated for potential use in the modeling. In addition, available analytical/empirical formulations of wind-induced waves, wave capacity to suspend the sediment, erosion and deposition of cohesive sediments (i.e., silt and clay), bioturbation, marine turbulence, and bed shear stresses will be reviewed to determine whether they should be incorporated in the TEMPEST/FLESCOT code.

3.6.2.2. Modification of the Model. The basic structure of the TEMPEST/FLESCOT code meets all the require ments, however, certain modifications will be made to the code to satisfy specific requirements for this study. These code modifications will be performed under this subtask. These modifications include incorporation of analytical/empirical formulations discussed in Section 3.6.2.1.

3.6.2.3. Field Sampling Support and Data Analysis. Under this subtask, physical and chemical field data on velocity, tide, wind, salinity, water temperature, sediment, PCBs, and a heavy metal will be analyzed in light of their use for the hydrodynamic and contaminant transport modeling. Collection of field data will be coordinated to incorporate data needed for modeling under this subtask.

3.6.2.4. Application of the Model. The TEMPEST/FLESCOT code will be applied to the Acushnet River/New Bedford Habor/Buzzards Bay system to predict the transport, distribution, and fate of PCBs and a heavy metal under this subtask. The modeling will include simula tion of four PCB isomers and one heavy metal for up to 10 years under selected combinations of base line conditions and four potential remedial action conditions.

3.6.2.5. Evaluation and Reporting. The model results, together with related field and laboratory data (distribution coefficients and possibly biodegradation data) will be evaluated to determine the effectiveness of selected remedial actions in reducing PCB and heavy metal concentrations in the study area. Quarterly progress and final reports related to hydrodynamic and contaminant transport modeling will also be prepared under this subtask.

3.6.3 Detailed Description of Subtasks

3.6.3.1. Review and Analysis of Existing Data. The objectives in this task are to review and evaluate existing physical and chemical data on water, bed sediment, and suspended sediment in the Acushnet River estuary/New Bedford Harbor/Buzzards Bay system in terms of their applicability for use in the sediment and contaminant transport code, TEMPEST/FLESCOT.

This three-dimensional code requires physical and chemical input data for setting the initial model conditions, for driving the model at the open boundary, and for calibration and assessment of the model. Existing data are used, to the extent possible, for setting the initial model conditions, calibrating the model, and assessing the model's performance. Depending on their quality, extent, and format, existing data can be used quantitively or qualitatively for this purpose.

Extensive data collection programs have been conducted in New Bedford Harbor since the discovery of PCB contamination in the mid-1970s. Studies have been conducted on the distribution of PCBs in bed sediments, in suspended sediments, and dissolved in water in the Acushnet River estuary, New Bedford Inner and Outer Harbor, and portions of Buzzards Bay. Some studies have included the vertical distribution of PCBs in bed sediments and the flux of contaminated suspended sediments through the inner harbor and estuary. Other studies have delt with the areal distribution of PCBs, the physical properties of bed and suspended sediments, current circulation patterns and magnitudes, and fluid characteristics in the vicinity of New Bedford Harbor. These studies have been conducted mainly by the U.S. Coast Guard, U.S. Environmental Protection Agency and its contractor, State of Massachusetts, and Woods Hole Oceanographic Institution. Other potentially useful data on the physical characteristics of New Bedford Harbor and Buzzards Bay, although not directly related to PCB contamination, are available through the U.S. National Weather Service, National Ocean Survey, U.S. Army Corps of Engineers, Woods Hole Oceanographic Institution, and other federal and state agencies.

A literature search and review of existing data will be performed to evaluate their applicability for use in providing initial conditions and for calibrating and assessing the TEMPEST/FLESCOT model. The literature search and review will concentrate on the physical, fluid, sediment, and sediment/contami nant characteristics as summarized below. Pertinent data will be compiled and rearranged into a format compatible with the TEMPEST/FLESCOT model as initial input data, calibration data, or assessment data.

The literature search/review will be performed early in the study so pertinent data can be incorporated to aid in calibrating the TEMPEST/FLESCOT model. Physical characteristics of New Bedford Harbor and Buzzards Bay necessary for modeling are as follows:

- bathymetry
- tides
- currents (magnitude and direction)
- vertical distribution of currents
- current circulation patterns
- wind and wind waves
- storm effects on water levels, currents, and circulation.

Fluid characteristics of New Bedford Harbor and Buzzards Bay necessary for modeling are as follows:

- areal and temporal distribution of salinity
- areal and temporal distribution of temperature

Sediment characteristics in New Bedford Harbor and Buzzards Bay necessary for modeling are as follows:

- physical characteristics of bed sediments
- areal and temporal distribution of suspended sediment concentrations
- areal and temporal distribution of suspended sediment concentrations
- physical and size characteristics of suspended sediments
- organic content of bed and suspended sediments
- wind/wave resuspension of bed sediments
- transport of sediment by currents.

Sediment/contaminant characteristics in New Bedford Harbor and Buzzards Bay necessary for modeling are as follows:

- areal and vertical distribution of PCBs and heavy metals in bed sediment
- partioning of PCBs and heavy metals between sand, silt, and clay size fractions in bed sediments
- PCB and heavy metal/organic material relationships
- PCB and heavy metal concentrations in suspended sediment opartioning of PCBs and heavy metals between sand, silt, and clay size fractions in suspended sediment
- dissolved PCB and heavy metal concentrations.

3.6.3.2. Model Modifications. The TEMPEST/FLESCOT computer code is well suited to simulate the mass and sediment transport processes in conjunction with the multidimensional hydro dynamic behavior of the Buzzards Bay system. Although certain modifications will be required to satisfy specific requirements at the Buzzards Bay site, the basic structure of the code meets all the requirements. The proposed modifications are listed below:

1. Expand boundary condition tables so that boundary current and winds can vary spatially in time.
2. Improve wind stress and bottom drag models affected by waves.
3. Improve turbulence model to handle anisotropic effects.
4. Include wave mechanisms to suspend the sediment.
5. Improve formulations for cohesive sediment deposition and erosion.
6. Include bioturbation.
7. Streamline to improve computation efficiency for the Buzzards Bay marine applications.
8. Improve input/output features to enhance user friendliness for specific marine applications at Buzzards Bay.

These planned modifications are described in more detail below.

Boundary Condition Tables. The base version of the code has a provision for specifying the magnitude of time and spatially varying boundary velocity; however, the direction of the velocity components cannot vary with time. It is expected that the capability to specify the direction and magnitude of the time-varying boundary velocity will be needed at Buzzards Bay. This modifica tion will require a small amount of reprogramming to expand the boundary condition tables.

Improved Wind Stress and Bottom Drag Models. The numerical model will use wind data collected at the Buzzards Bay site as input to simulate the effect of wind-driven surface currents. Wind magnitude and direction as a function of time will be required. The drag force exerted on the sea surface will incor porate this information through an appropriate correlation model that also involves sea surface roughness and wind-induced wave characteristics. The bottom drag correlations will also be incorporated to include wave effects on the seabed.

Turbulence Model. The base version of the code employs, as a user option, a k-e turbulence model that has been used quite successfully in a variety of engineered system analyses. This model is, however, considerably limited for marine applications because the computed effective viscosity is a scaler quantity. The TEMPEST turbulence model will need to be modified to account for at least two components of effective diffusion coefficients, one vertical and one lateral component, to more correctly represent the turbulence in the marine environment.

Wave Mechanisms. TEMPEST/FLESCOT does not include the wave mechanisms to suspend bed sediment. Because sediment suspension by wind-induced waves is one of the most important sediment transport mechanisms in the study area, especially during storms, the code will be modified to include the wave-suspension mechanisms. Currently, we anticipate that either the formulations of wave suspension mechanisms proposed by Grant and Glenn (1983), or those proposed by Liang and Wang (1973) for the off-shore zone and Komar (1977) for the surf-zone will be incorporated in the model. Another model developed at Battelle, the two-dimensional sediment/contaminant transport model, FETRA, already includes wave suspension mechanisms (Onishi et al. 1982a). These same mechanisms can also be included in TEMPEST/FLESCOT. If wave refraction is important in the study area, we plan to use the wave refraction model, LO3D (Ecker and DeGraca 1974).

Cohesive Sediment Deposition and Erosion. Currently, the TEMPEST/FLESCOT code includes formulations from Krone (1962) and Pertheniades (1962), to estimate amounts of deposition and erosion of fine sediments (silt, clay) and organic matter. However, this method is very arbitrary for selecting appro priate parameters to estimate the erosion and deposition of fine sediment. After careful evaluation, these formulations will be modified and incorporated in the model as proposed by W. D. Grant of the Woods Hole Oceanographic Institution or as proposed by Lick (1983).

Bioturbation. Because bioturbation is very active in the study area, TEMPEST/FLESCOT will be modified to include effects of bioturbation in the calculation of distributions of bed sediment and sediment-sorbed contaminants within the seabed. This is expected to entail only a small amount of work.

Streamlining. The current base version of the TEMPEST code is quite general and can simulate compressible flow, porous media flow, etc. in either Cartesian or cylindrical coordinates. Obviously, a number of these features are unnecessary for marine hydrodynamics and simply add to the computational burden. The features that are not needed for marine simulations will be eliminated, thus making the code computationally more efficient and economical to use. The effort is not envisioned to be large and should recover costs through savings in computer time.

Hydrodynamic Simulation Control. As mentioned previously, the major forces driving water motion in the Buzzards Bay system are tides and winds. Thus, in the absence of wind, tidal effects are the primary forces driving currents in the system. Tidally driven transport must be accounted for using time scales that are no longer than one-quarter of the tidal period. Conduct ing hydrodynamic simulations extending over many years would be prohibitively expensive using this time scale. However, a large degree of repetitiveness occurs in the flow field. For instance, in the absence of wind, the tidally induced motion is essentially the same for each tidal cycle. Winds from a certain direction and for a certain duration will develop currents in the systems that are similar. Likewise, resulting inertial currents will decay in a similar way for similar conditions. Simulations of short-duration phenomena (e.g., storms), extending from one to several days, will be simulated without repetitions.

The strategy for simulating long-term transport will be to compute short-term velocity fields for a tidally driven base case and for several typical wind-driven cases. These fields will then be used repetitively to simulate mass/energy transport in a manner consistent with expected conditions based on historical data. Note that mass/energy transport will be continuously simulated. This strategy will improve the computational efficiency of the model for analyzing the Buzzards Bay system by eliminating most of the long-term hydrodynamic calculations that otherwise would be required. The transport simulations, however, must be conducted on a continuous basis.

Because spatial variation of the tidally induced hydraulic head will be small over the Buzzards Bay reach, the water surface may be assumed flat. Thus, the tidal influence can be modeled by varying the water surface elevation uniformly over the modeled region with time. This technique was used success fully in a recent simulation of Sequim Bay on the Strait of Juan de Fuca (Elston et al. 1983). An option to simulate the tidal effects in this fashion will be provided.

3.6.3.3. Field Sampling Support and Data Analysis. The objectives of this subtask are to provide support to Battelle New England Laboratory and Woods Hole Oceanographic Institution on the physical and chemical data collection needs for input to the sediment and contaminant tran sport model, TEMPEST/FLESCOT, and to analyze the reduced field data provided by Battelle New England Laboratory; Woods Hole Oceanographic Institution; and others for incorporation into the TEMPEST/FLESCOT model.

Woods Hole Oceanographic Institution will be conducting field studies on the hydrodynamic and fluid characteristics of New England Harbor and Buzzards Bay to be used as open boundary conditions and for calibration and assessment of the TEMPEST/FLESCOT model. These studies will include surface drifter deployments in the vicinity of New Bedford Harbor to describe local circulation patterns, continuous current magnitude and direction data at the open boundary, and CTD data elsewhere in Buzzards Bay. The Battelle New England Laboratory will be collecting field data on sediment and sediment/contaminant characteris tics at the same time as the hydrodynamic and fluid characteristics data are being collected by Woods Hole Oceanographic Institution. These data include bed and suspended sediment characteristics, and PCB/heavy metal concentrations on bed sediment, suspended and dissolved in water. Upon receiving the reduced field data from Woods Hole Oceanographic Institution and Battelle, New England Laboratory, Battelle-Northwest will screen and synthesize the data before incorporating it into the TEMPEST/FLESCOT model.

Certain other data not included in the field sampling program are required to calibrate and/or assess the TEMPEST/FLESCOT model. These include data on current circulation patterns throughout Buzzards Bay and wind wave generation within Buzzards

Bay. Current circulation data to be collected by Woods Hole Oceanographic Institute will cover only a small portion of Buzzards Bay. To calibrate the TEMPEST/FLESCOT hydrodynamic code, current circulation data are required over the entire Buzzards Bay. Current circulation in coastal waters can often be inferred by evaluating suspended sediment patterns through the enhancement of satellite imagery at different stages of the tidal cycle. Battelle-Northwest will acquire Landsat 4 and 5 imagery of Buzzards Bay, enhance the imagery with state-of-the-art enhancement techniques and evaluate the current circulation patterns in Buzzards Bay. Overlay charts of the circulation patterns at representative stages of the tidal cycle will be prepared from the imagery. These charts will show the circulation patterns and relative magnitude of the currents. The charts will be used to confirm the circulation patterns produced by TEMPEST/FLESCOT.

Wind/wave activity is a principal mechanism for resuspending bed sediments contaminated with PCBs and heavy metals. The TEMPEST/FLESCOT model computes the generation of waves by wind through empirical relationships that were developed by the U.S. Army Corps of Engineers. Some wave records are available through the Corps of Engineers who maintained a wave gage near the New Bedford Harbor hurricane barrier for a number of years. These wave records will be correlated with wind records at New Bedford for the same time period, and then be used to calibrate and assess the wind/wave generation code in the TEMPEST/FLESCOT model.

3.6.3.4. Application of the Model. The modified TEMPEST/FLESCOT code will be applied to the study are to predict four PCB isomers and one heavy metal. TEMPEST/FLESCOT data requirements are rather extensive, as indicated below:

INPUT DATA:

- bathymetry
- fluid characteristics
  - initial conditions
  - salinity distribution
  - water temperature distribution
- flow characteristics
  - bed drag coefficients
  - wind direction and speed -boundary conditions
    - -- tidal elevation change with time
    - -- current change with time

- wave characteristics

  - wave height, period, etc., either from LO3D or other wave refraction models

  - average fetch length and fetch depth to calculate waves from wind data with TEMPEST/FLESCOT

- sediment characteristics

  - initial conditions

    -- bed sediment size distribution (sand, silt/clay, organic matter)

    -- bed sediment density

    -- bed sediment porosity

    -- suspended sediment concentrations for the three sediment size fractions

  - boundary conditions

    -- suspended sediment concentrations and their size distributions

  - for silt/clay and organic matter

    -- critical shear stress for erosion

    -- critical shear stress for deposition

    -- erodibility coefficient

  - activity of bioturbation

- contaminant characteristics

  - distribution coefficients of PCBs/heavy metals for each size fraction of suspended and bed sediment

  - time to reach equilibrium adsorption conditions of PCBs/heavy metals with suspended and bed sediments for the three sediment size fractions

  - PCB/heavy metal degradation and volatilization rates, where applicable

  - initial conditions

-- distributions of dissolved PCB/heavy metal concentrations

-- distributions of sediment-sorbed PCB/heavy metal concentrations for suspended sediments for the three sediment size fractions

-- distributions of sediment-sorbed PCB/heavy metal concentrations for bed sediments of the three sediment size fractions

- boundary conditions

  -- time-varying dissolved PCB/heavy metal concentrations at the boundary

  -- time-varying sediment-sorbed PCB/heavy metal concentraitons associated with the three sediment fractions of suspended sediment at the boundary

  -- PCB/heavy metal release rates from outside sources (e.g., municipal sewage effluent) either as a bulk sum of dissolved and sediment-sorbed phases, or individually as the dissolved phase and the three sediment-sorbed phases

These necessry data will be collected through field and laboratory measurements, as disscussed in Subtask 3.6.3.

With these available data, the code will simulate the following:

- velocity and depth
- water temperature
- salinity (if necessary)
- sand
- cohesive sediment (silt/clay)
- organic material that is independent of inorganic sediment (if necessary)
- four PCB pseudo-isomers
- one heavy metal.

TEMPEST/FLESCOT will simulate the transport of each PCB pseudo-isomer and heavy metal as a separate run.

Step 1 Calibration. The code will be calibrated under summer (stratification), winter (no stratification), and storm conditions. First, field data taken in the summer will be used to initiate the model calibration. Specifically, the hydrodynamic portion of the code will simulate the flow distributions during the summer with varying wind conditions as a calibration process. This model exercises will provide most of required hydrodynamic parameter adjustment and will indicate whether the hydrodynamic simulation is adequate. Field sediment data collected during the summer, together with laboratory data supplied by the Wood Hole Oceanographic Institute, will also be used to adjust model parameters related to sediment transport. However, these adjustments are preliminary because the submodel for sediment transport requires the storm conditions to complete the calibration. The calibration of the contaminant (PCB and heavy metal) transport submodels will also be initiated with the summer data. Parameters for the contaminant transport submodels are dispersion coefficients that will be determined jointly with salinity, water temperature, and sediment transport. Hence, the major calibration process for TEMPEST/FLESCOT is accomplished through the sediment transport submodel.

When winter and storm data become available, the sediment transport submodel will be further calibrated with these data. The three data sets for widely varied conditions (summer, winter, and storm cases) will also indicate whether the calibration is adequate for sediment and contaminant (PCB and heavy metal) transport.

Other submodels (e.g., hydrodynamic, salinity, water temperature) will use the winter and storm condition data for further testing to increase confidence in the modeling.

Step 2 Calibration Evaluation. As discussed in Step 1, all submodels of TEMPEST/FLESCOT will be evaluated using the three sets of data collected under summer, winter, and storm conditions. For the sediment-transport submodel, at least summer and storm data will be needed, but most likely all three sets of data will be necessary for its calibration.

Step 3 Baseline Case Production Runs. The major forces driving water motion in the Buzzards Bay system are tides and winds. Hence,a long-term scenario (up to 10 years) will be constructed with historical tide and wind data.

The strategy for simulating long-term transport with the short-term velocity field is discussed in the Hydrodynamic Simulation Control section.

After development of the long-term scenario for the flow condition, transport of PCBs and a heavy metal will be simulated for the entire Buzzards Bay system, including the New Bedford Harbor and the Acushnet River, for approximately 10 years without remedial actions as a baseline condition. If dredging is performed in the inner New Bedford Harbor in the next summer, that condition may be used as the baseline condition. The long-term prediction of PCB and a heavy metal will then be supplied for the food chain modeling.

In addition to the long-term baseline condition, a short-term, but more detailed simulation of selected PCB and heavy metal transport in the Acushnet River Estuary and the New Bedford Harbor. This will be accomplished using the results obtained from the long-term simulation for the baseline condition for the outer edge of the New Bedford Harbor. This will provide a more detailed assessment of transport, accumulation, and resuspension patterns of PCBs and heavy metals in these areas, which are heavily contaminated.

Step 4 Remedial Action Case Production Runs. In addition to baseline condition discussed above, we plan to simulate the transport of PCBs and a heavy metal under four selected remedial conditions. The actual remedial actions studied here will be generated by the U.S. Environmental Protection Agency, the NUS Corporation, and this project team jointly. It is currently envisioned that these remedial actions are:

- three dredged conditions
- barrier containment in the Acushnet River.

For these cases, TEMPEST/FLESCOT will simulate long-term transport, accumulation, and resuspension of PCBs and a heavy metal in the entire Buzzards Bay. In selected cases (similar to the Step 3 applications), shorter but more detailed simulations may be performed for the Acushnet River and the New Bedford Harbor.

The results obtained under Step 4 will then be supplied to the food chain modelers to determine the effectiveness of each proposed remedial action on biota.

Output: Simulation output of TEMPEST/FLESCOT are time-varying, three-dimensional distributions of:

- flow (velocity of water depth)
- water temperature

- salinity (if needed)
- sediments
- dissolved PCB isomers and a heavy metal in water column
- particulate PCB isomers and a heavy metal in water column
- bed erosion and deposition and bed sediment size distribution
- particulate PCB isomers and a heavy metal in the seabed.

These results will be provided either as:

- print-out
- two-dimensional hard-copy plots
- a movie or videotape of selected simulation results, if additional funding is provided.

3.6.3.5. Evaluation and Reporting. The objectives of this subtask are to coordinate the physical/chemical modeling tasks (Battelle-Northwest), field sampling tasks (Woods Hole Oceanographic Institution and Battelle New England Laboratory), and food chain modeling tasks (HydroQual) and to coordinate preparation of quarterly progress and final reports.

One start-up meeting and five quarterly progress meetings will be attended by Battelle Northwest to coordinate the physical/chemical modeling efforts and to communicate results to the food chain modeling effort. Status reports on the progress of the physical/chemical modeling effort will be provided at the quarterly meetings. The following is a summary of Battelle-Northwest's inputs to the quarterly meetings:

Start-up Mtg	June 11, 1984	Scheduling and Work Plan
1st Quarterly Mtg. Rpt	August 27, 1984	Results of initial physical/chemical model modifications and requirements for food-chain model
2nd Quarterly Mtg. Rpt	November 26, 1984	Results of completed physical/chemical model modifications
3rd Quarterly Mtg/Rpt	February 25, 1985	Results of physical/chemical model calibration

4th Quarterly Mtg/Rpt	May 27, 1985	Results of physical/chemical model verification and progress on modeling base condition
5th Quarterly Mtg/Rpt	August 26, 1985	Results of physical/chemical modeling of base condition and remedial action alternatives

The physical/chemical and food chain modeling efforts require close interfacing to ensure that scheduling deadlines are met. This will require additional coordination between Battelle-Northwest and HydroQual beyond the quarterly progress meetings. The major coordination and input between Battelle-Northwest and HydroQual are summarized below:

Define physical/chemical input requirements for food-chain model	July 27, 1984
Coordinate modifications to physical/chemical model	October 26, 1984
Coordinate calibration and verification of physical/	May 17, 1985 chemical model
Provide results of physical/chemical modeling base conditions to HydroQual	June 14, 1985
Provide results of physical/chemical modeling of remedial action alternatives to HydroQual	June 24, 1985 - August 30, 1985

A draft final report will be prepared describing the physical/chemical modeling effort. The report will include a description of the TEMPEST/FLESCOT sediment and contaminant transport model, modifications to the model for application to New Bedford Harbor/Buzzards Bay, calibration and assessment of the model using existing data and data collected during the field sampling program, and modeling results of the base condition and remedial action alternatives. The draft final report will be submitted to Battelle New England Laboratory in September, 1985.

APPENDIX A

HYDRODYNAMIC AND CONTAMINANT TRANSPORT COMPUTER CODE SELECTION

APPENDIX

HYDRODYNAMIC AND CONTAMINANT TRANSPORT COMPUTER CODE SELECTION

To simulate the hydrodynamics and transport of mass/energy (e.g., salinity, water temperature, sediments, PCBs, and heavy metals) in the Acushnet River/New Bedford Harbor/Buzzards Bay system, a numerical model must be used that can address all of the important physical/chemical/biological phenomena that can impact the transport processes. This is necessary both to accredit the modeling scientifically and to render the numerical model useful as a predictive/diagnostic tool.

Specifically, hydrodynamic phenomena that need to be addressed are

- three-dimensional distribution of pertinent physical quantities
- time dependence of these quantities
- tidal currents
- ambient stratification/buoyancy affected by salinity, water, temperature, and possibly suspended-sediment concentration
- vertical and lateral component of locally generated turbulence
- tidal changes
- surface wind shear/drag
- recirculation.

Sediment transport phenomena that need to be addressed are as follows:

- advection and dispersion
- suspension of sediment by wind-induced waves
- sediment fall velocity and cohesiveness
- deposition on the sea bed
- erosion from the seabed
- bioturbation effects in the seabed.

PCB and heavy metal transport phenomena that need to be considered are as follows:

- advection and dispersion of dissolved and sediment-sorbed contaminants
- adsorption/desorption
- chemical and biological degradation
- volatilization (for PCB)
- deposition of sediment-sorbed contaminants to the sea bed
- erosion of sediment-sorbed contaminants from the sea bed
- PCB and heavy metal releases from outside sources (e.g., from municipal sewage effluent).

Therefore, the numerical model needs to possess the following capabilities:

- full three-dimensionality for physical space
- time-dependent solution procedures
- full three-dimensional solution for hydrodynamics, which considers inertial effects, turbulent viscosities, surface and bottom drag, and buoyancy coupling
- space/time-dependent boundary conditions
- mechanistic turbulence model that accounts for turbulence transport, generation, and dissipation. The model must also account for heterogeneous and anisotropic effects.
- ability to simulate tidal changes
- full three-dimensional solution for energy (water temperature) transport

  full three-dimensional solution for salinity transport
- full three-dimensional solution for sediment transport
- full three-dimensional solution for dissolved contaminant transport

- full three-dimensional solution for sediment-sorbed contaminant transport
- full three-dimensional solution for sediment/contaminant deposition on the seabed.

Additionally, the following features are desirable for the numerical model:

- ease of use
- applicability to a variety of environmental conditions
- reasonably fast running (for a model having the capabilities listed above)
- post processor package that produces a variety of graphics output.

Recently, various studies have been done to review available contaminant transport models (Hoffman et al. 1978; Onishi et al. 1981; Boutwell and Roberts 1983). These reports indicate that only a few models simulate contaminant transport with sediment interactions (e.g., adsorption/desorption; transport, deposition, and erosion of sediment and sediment-sorbed contaminants). As shown in Tables 3.6.1 and 3.6.2, these models are TEMPEST/FLESCOT (Onishi and Trent 1982), FETRA (Onishi 1981), SERATRA, TODAM (Onishi, Whelan and Skaggs 1982) and CHNSED (Field 1976). Among them, only the three-dimensional model, TEMPEST/FLESCOT, and the two-dimensional model, FETRA are applicable to estuaries and coastal waters.

Overall the existing time-dependent three-dimensional code, TEMPEST-/FLESCOT, (developed at Battelle-Northwest) has the basic capabilities and features needed for this study (Onishi and Trent 1982; Trent, Eyler and Budden, 1983). TEMPEST/FLESCOT is a time-varying three-dimensional model that predicts

- distribution of flow affected by many factors including tides and wind
- distribution of water temperature
- distribution of salinity
- distributions of sediments for three sediment sizes/types
- distribution of dissolved contaminant

TABLE 3.6.1. SUMMARY OF RADIONUCLIDE-TRANSPORT MODELS (ADAPTED FROM ONISHI ET AL., 1981).

AUTHOR AND OR MODEL	TRANSPORT MODELED: DISSOLVED RADIONUCLIDES	TRANSPORT MODELED: PARTICULATE RADIONUCLIDES	TRANSPORT MODELED: SEDIMENT	MECHANISMS: ADVECTION	MECHANISMS: DIFFUSION DISPERSION	MECHANISMS: ADSORPTION	MECHANISMS: RADIOACTIVE DECAY	HYDRODYNAMICS SIMULATION	DIMENSIONALITY: NONE COMPARTMENT	DIMENSIONALITY: 1D	DIMENSIONALITY: 2D	DIMENSIONALITY: 3D	TIME DEPENDENCE: STEADY STATE	TIME DEPENDENCE: DYNAMIC	SOLUTION TECHNIQUE: ANALYTICAL	SOLUTION TECHNIQUE: NUMERICAL	WATER BODY	FIELD APPLICATION
FLETCHER AND DOTSON 1971	x	x	x	x			x			x				x		FD	R,L	
BRAMATI et al 1973	x			x		x				x			x		x		R,L	x
SOLDAT et al 1974	x	S		x		x	x			x			x			FD	C,E,R,L	x
WATTS 1976	x			x			x			x			x		x		R	x
MARTIN et al 1976	x			x			x			x				x		FD	R,L	x
BUCKNER AND HAYES 1976	x	x		x	x	x	x			x				x		FD	R	x
SHIH AND GLOYNA 1976	x	B		x	x	x				x				x	x		R	
ARMSTRONG AND GLOYNA 1968	x	B		x	x	x				x				x		FD	R	
WHITE AND GLOYNA 1969	x	B		x	x	x				x				x		FD	R	
SHULL AND GLOYNA 1968	x	x		x		x				x			x		x		R	
ONISHI et al 1976																		
1977 1978 1979 1981 1982																		
FETRA	x	x	x	x	x	x	x				x		x	x		FE	C E R	x
SERATRA	x	x	x	x	x	x	x				x			x		FE	R,L	x
TODAM	x	x	x	x	x	x	x			x				x		FE	R,E	x
FLESCOT	x	x	x	x	x	x	x	x				x		x		FD	R,E,C,L	x
FIELDS 1976 (CHNSED)	x	x	x	x		x				x				x		FD	R	
ERASLYN et al 1977																		
RADON	x			x	x					x				x		FD	E,R	
RADTWO	x			x	x						x			x		FD	C,E,L	
HOTSED		x	x			x		x		x				x		FD	E,R	
CHAPMAN 1977		x		x	x	x	x			x				x		FD	R	
SMITH et al 1977	x	x		x	x	x	x		x				x			FD	RL	x
VANDERPLOEG et al 1976	x	x				x	x		x					x	x		L	x
BOOTH 1976	x	x				x	x		x					x	x		L	
USNRC ESTUARINE MODEL 1978	x	x		x	x	x	x			x				x	x		E	x
FALCO ONISHI AND ARNOLD	x	x		x		x	x			x				x	x		R	
CHURCHILL 1976	x	x		x		x	x			x	x			x		FD	E	x
OCONNOR AND FARLAY 1980	x	x		x		x	x	x			x		x			FD	E	x
USNRC RIVER MODEL 1978	x	x		x		x	x			x			x		x		R	x
USNRC LAKE MODEL 1978	x	x		x		x	x		x				x		x		L	x
DITORO et al 1981	x	x	x	x	x	x	x		x					x		FD	R,E,L	x

S FOR SHARE SEDIMENMT ONLY B FOR BED SEDIMENT ONLY

FD FINITE DIFFERENCE FE FINITE ELEMENT I INTEGRATION

C COASTAL SYSTEM AND GREAT LAKES E ESTUARINE SYSTEMS R RIVER SYSTEMS L LAKES AND IMPOUNDMENTS

TABLE 3.6.2. SELECTED CHEMICAL FATE MODELS FOR SURFACE WATER SYSTEMS.

Model	Transport: Water	Transport: Sediment	Transformation: Biotransformation	Transformation: Hydrolysis	Transformation: Oxidation Reduction	Transformation: Precipitation/ Dissolution	Transformation: Photolysis	Transformation: Radioactive Decay	Transfer: Sorption	Transfer: Volatilization	Transfer: Bioaccumulation	Applicability	Dimensionality: Spatial	Dimensionality: Temporal	Degree of Testing
TODAM	x	x	x	x	x		x	x	x	x		Non-tidal Rivers Estuaries	1-D	Dynamic	Applied to radionuclides in Los Alamos, NM and diazinon in Monticello research channels
SERATRA (Onishi and Wise 1979)	x	x	x	x	x		x	x	x	x		Non-tidal rivers, flow through reservoirs	2-D (vertical/ longitudinal)	Dynamic	Applied to radionuclides in Clinch River Tennessee and Columbia River, Washington, and Alachlor in Fourmilk Creek, Iowa. Verification testing currently being con- ducted in Cattaraugus Creek, NY.
FETRA (Onishi 1981)	x	x(a)						x	x			Estuaries, coastal waters	2-D (lateral/ longitudinal)	Dynamic	Applied to radionuclides off Japanese coast and Irish Sea. and Kepone in James River, Virginia.
FLESCOT (Onishi and Trent 1981)	x(b)	x						x	x			Estuaries, lakes Coastal waters	3-D	Dynamic	Applied to radionuclides in Hudson River estuary, New York
EXAMS (Smith et al. 1977	(c)	(d)	x	x	x		x	x	x	x	x	Rivers, lakes	Compartment	Steady-State	Receiving extensive use by industry, universities, EPA, other Federal agencies and several foreign groups. Model has been tested against results obtained from laboratory protocols, microcosms and field studies.
TOXIWASP	(c)	(d)	x	x	x		x	x	x	x	x	Rivers, lakes, estuaries	Compartment	Quasi-Dynamic	Model tested against EXAMS hypothetical environments and applied to upper Yazoo River, Mississippi.
HA Model												Rivers, lakes, estuaries	Compartment		
TOX... (Schnoor 1981)	x	x	x	x			x		x	x	x	Rivers, lakes, estuaries	Compartment	Dynamic	Applied to several rivers and lakes in Iowa, including Coralville Reservoir.
PEST (Park et al. 1980)												Lakes	Compartment	Dynamic	
HSPF (Johanson et al. 1980)	x	x	x	x	x		x	x	x	x	x	Watersheds, nontidal rivers	Compartment	Dynamic	Hydrologic component has received exten- sive testing. Sediment and chemical fate components have been tested on several field size catchments and Fourmile Creek, Iowa.
SRI Model (Smith et al. 1977)	(c)	(d)	x	x	x		x		x	x	x	Rivers, lakes	Compartment	Steady-State	Used to test results of laboratory protocols for transformation and transfer rate constants

(a) Includes sediment transport from wind induced wave action
(b) Includes salinity and temperature
(c) Water flux between compartments must be specified
(d) Sediment flux between compartments must be specified

- distributions of particulate contaminants sorbed by three sizes/types of sediments

- distribution of sediment and particulate contaminants in the estuarine/seabed.

The TEMPEST computer code was developed for the U.S. Government over a period of six years (1977-1983) for application to general three-dimensional, time-dependent, hydrothermal analysis of reactor systems (Trent, Eyler and Budden, 1983). We are continuing to develop the code to extend its application to other areas. The code has a long verification and assessment history (Eyler, Trent and Budden 1983) for closed-system hydrodynamics. Simulations using the marine version of the code, FLESCOT, have been performed for transport of sediments and toxic contaminants in estuaries and bays over the past several years (Onishi and Trent 1982), and buoyant plume simulations have been con ducted for the thermal plume in the Columbia River (Lombardo and Eyler 1982).

The TEMPEST/FLESCOT code is the best suited hydrodynamic/mass transport computer code available for the analysis of contaminant transport in Buzzards Bay. Although certain modification will be required to satisfy specific requirements at the Buzzards Bay site, the basic structure of the code meets all the requirements. The proposed modifications are listed below.

1. expand boundary condition tables so that boundary current and winds can vary spatially in time
2. improve wind stress and bottom drag models affected by waves
3. improve turbulence model to handle anisotropic effects
4. include wave mechanisms to suspend the sediment
5. improve cohesive sediment deposition and erosion models
6. include bioturbation
7. streamline to improve computation efficiency for the Buzzards Bay marine applications
8. improve input/output features to enhance user friendliness for specific marine applications at Buzzards Bay.

3.7 BIOLOGICAL FOOD WEB MODELING

It is proposed to conduct a detailed evaluation of the contamination of important fish species to interface and proceed simultaneously with the physico-chemical evaluations. The proposed work supplements the physico-chemical analysis, and provides the means by which the effectiveness of remedial activity on lowering PCB and copper body burdens in important fin- and shellfish can be assessed.

It is proposed that an existing detailed food web modeling framework (Hydroscience, Inc., 1978, 1979; HydroQual, Inc. 1981a,b; Thomann, 1981; Thoman and St. John, 1979; Thomann and Connolly, 1984; Connolly and Tonelli, 1984) be applied to important sectors of the New Bedford marine ecosystem. This recommendation is made so that a mechanistically realistic analysis is developed for evaluation of remedial activity. Two primary pathways exist for transfer of PCB to top predator fin- and shellfish: direct uptake from water, and from ingestion of contaminated prey. Much laboratory work has been performed on various organisms to define the PCB bioconcentration factor (organism concentration/water concentration) which results in individual species. If uptake from water was the only or principal pathway by which PCB is transferred to the organism, the concentration factors could be used directly to assess organism PCB changes as water column values are reduced by remedial actions.

However, field studies have shown that PCB concentration factors may exceed laboratory-derived values by substantial margins. Figure 3.7.1 shows a comparison of PCB concentration factors obtained from both laboratory and field data as a function of organism size (Thomann and St. John, 1979; Thomann, 1981). It is observed that in the range of organism size from 0.1 to 1.0 m, the upper bound of field-derived concentration factors is approximately a factor of 10 greater than those derived from water uptake laboratory experiments only. This suggests that food web transfer is an important and predominant pathway for PCB accumulation in the higher trophic levels. Food web calculations have confirmed that PCB in top predators derives almost entirely from consumption of contaminated food (Hydroscience, Inc., 1979; HydroQual, Inc., 1981; Thomann, 1981; Thomann and Connolly, 1984). Unless food web transfer is properly considered in the analysis, the effectiveness of various remedial actions may be substantially overstated and the time sequence of changes improperly defined.

A number of specific project tasks are required to achieve the basic objectives of the study. Technical descriptions of the various tasks are presented as follows:

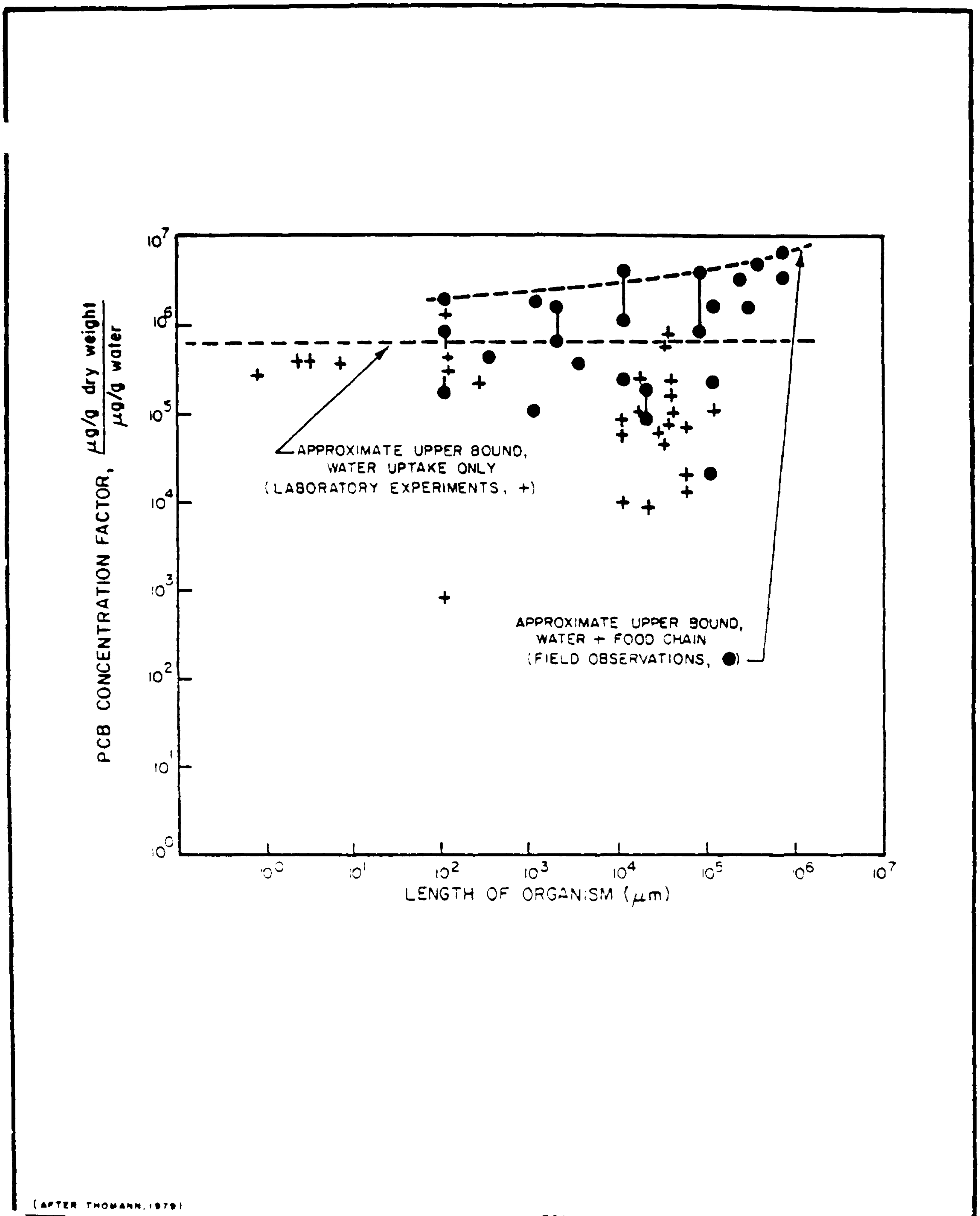


FIGURE 3.7.1. PCB CONCENTRATION FACTORS FROM LABORATORY EXPERIMENTS AND FIELD OBSERVATIONS.

3.7.1 Task 1 - Evaluation of Existing Data

The data required for the food web model consist of values for the parameters used in the model and field measurements of sediment, water, and aquatic animal PCB and copper concentrations. Ranges of values for the parameters may be obtained from previous laboratory and field studies. Therefore, it is proposed that an extensive review of the literature be conducted to compile the available information for the following parameters: (1) respiration rate, (2) growth rate, (3) migratory habits, (4) food assimilation efficiency, (5) contaminant assimilation efficiency, (6) contaminant bioconcentration factor, and (7) contaminant excretion rate. Values for the first four parameters will be obtained specifically for the species being modeled. However, for the last three parameters, which relate to the contaminant (PCB and copper), little information is available for the species being modeled. For these parameters, the literature review will include other species. The resulting information will provide a first estimate of the parameter values as well as a check on the values which will be obtained from studies to be conducted as part of this project.

A substantial amount of field data are presently available from the New Bedford area. Sampling and laboratory analyses of PCBs and some heavy metals for sediment, water, and biological specimens have been conducted at various times from 1976 to the present by the following organizations:

- U.S. EPA
- Massachusetts Division of Marine Fisheries
- Massachusetts Department of Environmental Quality Engineering
- Massachusetts Division of Water Pollution Control
- National Marine Fisheries Service of NOAA
- U.S. Coast Guard
- Woods Hole Oceanographic Institution (W.H.O.I.)
- Southeastern Massachusetts University
- Camp, Dresser and McKee

- Versar
- GCA Corporation

It is proposed that these data be reviewed with particular emphasis on biological information characterizing the distribution of PCB and copper in the ecosystem. Specifically, data will be evaluated for the principal species of concern: northern lobster, winter flounder, the hard clam, and the associated food chains including crabs, mussels, polychaetes, and other benthic invertebrates. Spatial trends of PCB and copper contamination levels in the various trophic levels will be defined. The information will also be evaluated to define seasonal and/or annual trends in various geographical areas for the species of interest. Relationships between contaminant body concentration and species age and weight will be established for the specific biological species of concern. Further, PCB and copper concentration factors for the important organisms will be developed, as possible, from water column and sediment contaminant concentration values, similar to the analysis shown in Figure 3.7.1. In all cases, the statistical variability of data will be considered in the analysis.

The output from this task will be a detailed review of available data, data reductions which are required to assess the existing characteristics of the PCB and copper contamination of the ecosystem, and data workups necessary for the balance of the technical analysis.

3.7.2 Task 2 - Application of Biological Food Web Model

A generalized model of the uptake and accumulation of PCBs by biological organisms was developed by HydroQual personnel as part of the study entitled, Analysis of the Fate of PCBs in the Ecosystem of the Hudson Estuary which was performed for the New York State Department of Environmental Conservation (Hydroscience, 1978). A generalized overview of this model, as applied to the Hudson River system, is illustrated in Figure 3.7.2.

The diagram schematically illustrates the various factors affecting the physico-chemical distribution of PCBs in the water column: external (point and nonpoint source) inputs, settling of PCBs attached to particulates, sediment PCB release and resuspension, downstream transport and volatilization. All of these factors interact to

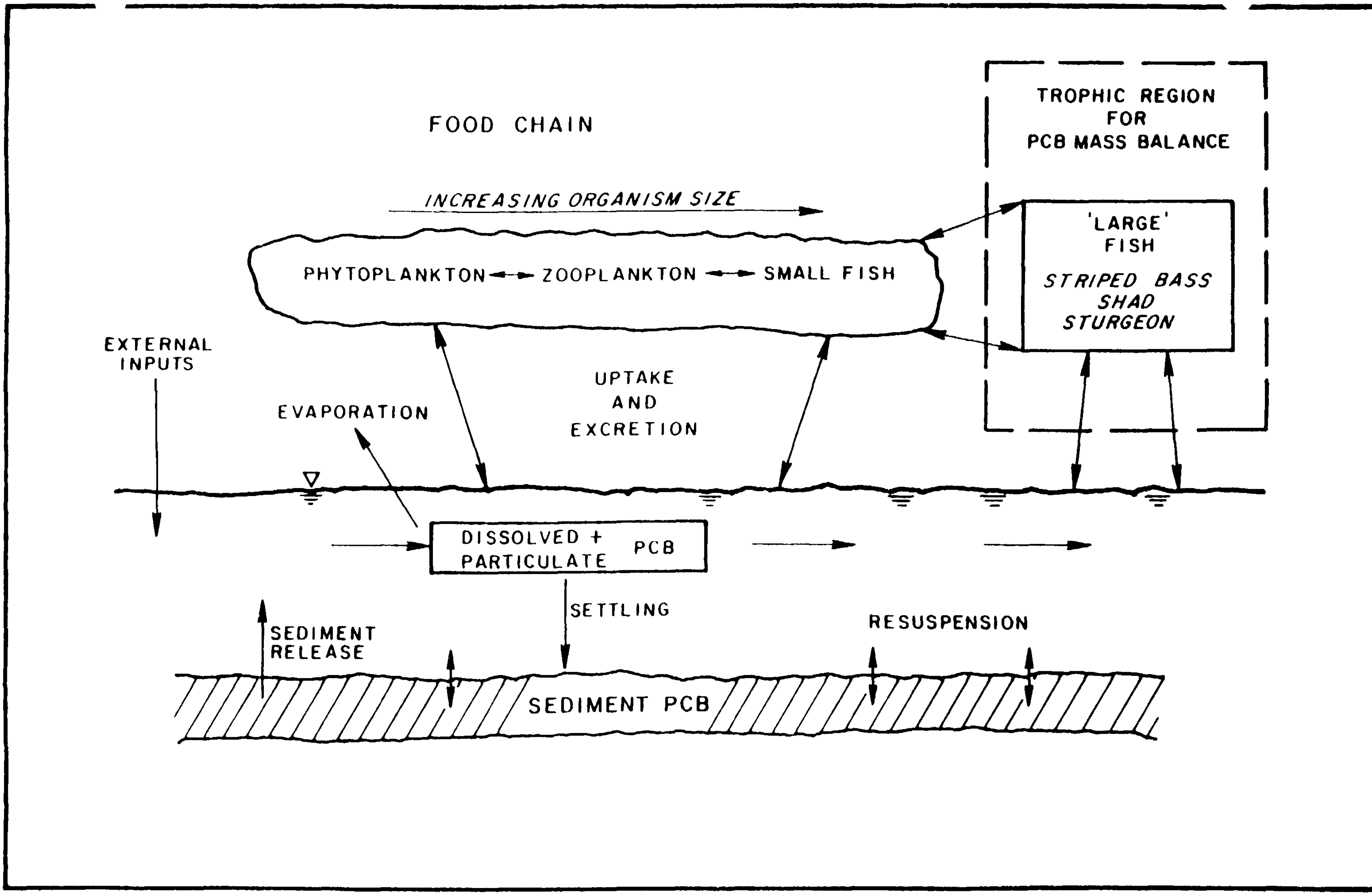


FIGURE 3.7.2. SCHEMATIC OF MAJOR FEATURES IN PCB DISTRIBUTION THROUGHOUT FOOD CHAIN

produce specific dissolved and particulate PCB concentrations in the water column and sediment. Water column PCB then enters the food web directly at various trophic levels (phytoplankton, zooplankton, small fish) through net uptake and excretion and is also transported through the food web by sequential organism predation. At the top predator level, the important commercial/recreational fish of interest (striped bass, shad, sturgeon) received PCB input from predation on contaminated smaller species and directly from the water column. As previously indicated, 90 percent or more of the PCB body burden in the top predator may originate via the food web route as compared with direct uptake from the water column by gill activity and sorption.

Additional detail on the food web model as applied in the Hudson River is provided in Figure 3.7.3. As shown, a seven compartment food web model was used to predict the accumulation of PCB into a top predator, the striped bass. The PCB concentration or body burden in each food web compartment is a function of the ambient PCB concentration in the water column and sediment, the PCB uptake and excretion rate of the particular organism and the feeding habits of the organism. The model is generalized in the sense that a variety of food web compartments and feeding pattern interactions can be considered. Additionally, model inputs such as PCB uptake and excretion rates, PCB assimilation efficiencies, and specific consumption rates can be adjusted in each food web compartment in order to determine the sensitivity of the calculated body burdens to changes in these input parameters.

It is proposed to apply this modeling approach to the New Bedford area. Food web structures will be developed for the selected species of interest as shown on a preliminary basis, in Figures 3.7.4 and 3.7.5 for the lobster and winter flounder. For each species, a detailed review of the literature (Task 1) will be performed to define the nature of the prey, feeding habits, respiration characteristics, age-weight relationships, and migratory patterns. Further, literature values will be sought for food consumption rates, PCB and copper excretion rates, and any previously observed PCB and copper bioconcentration factors and contaminant sediment/benthic organism partitioning. The food web model is then applied to the Acushnet Estuary/New Bedford Harbor/Buzzards Bay area. The waterways in the region will be segmented as appropriate to account for differences in water column and sediment PCB and copper concentration levels. The model is dynamic in nature and accounts not only for spatial variability of contaminant concentrations, but also changes of water column and sediment concentrations with time and organism aging.

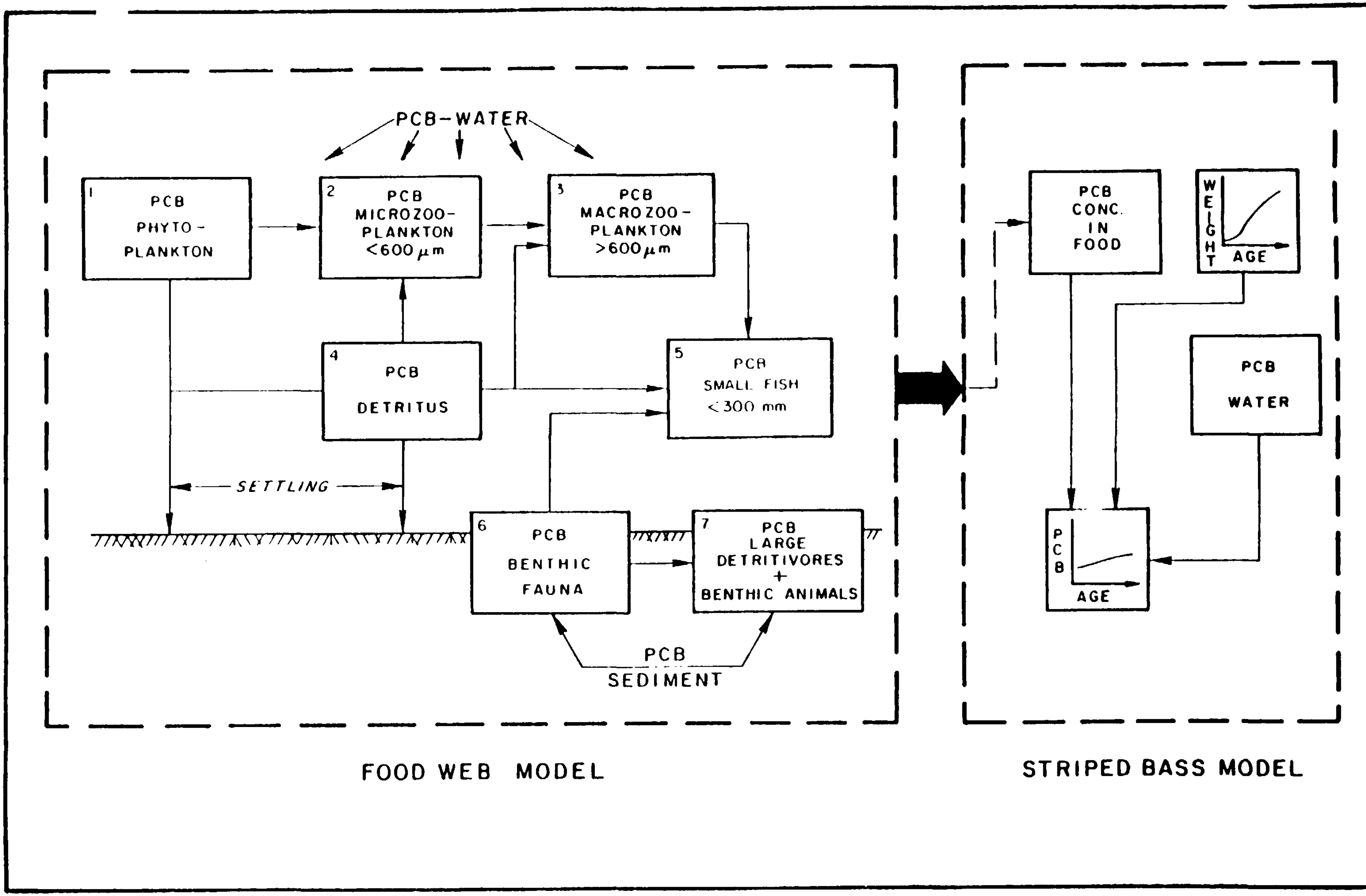


FIGURE 3.7.3. SCHEMATIC OF COMPARTMENTS IN FOOD WEB MODEL AND STRIPED BASS (*Morone saxatilis*) MODEL

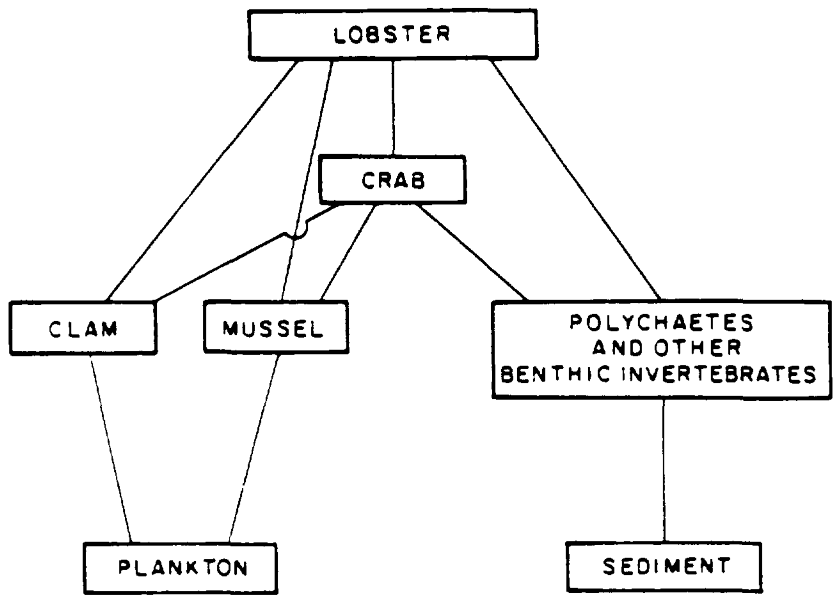


FIGURE 3.7.4. LOBSTER (Homarus americanus) FOOD CHAIN

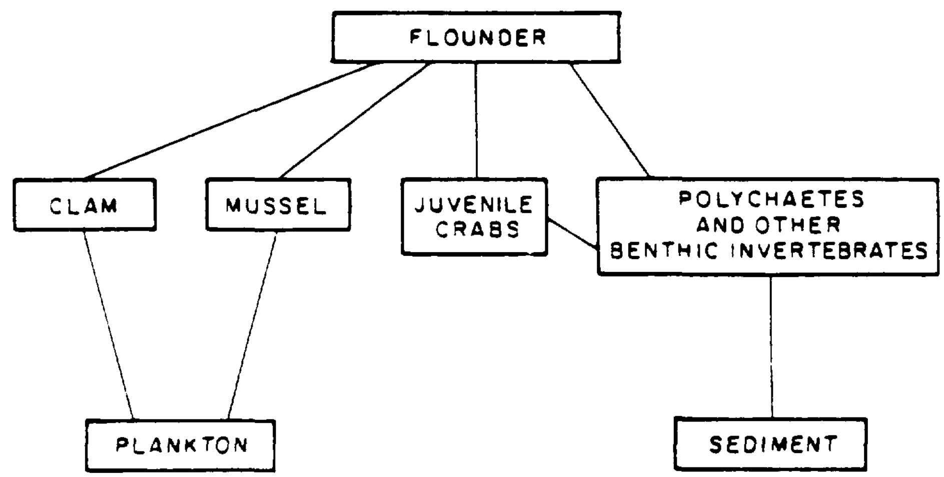


FIGURE 3.7.5. WINTER FLOUNDER (Pseudopleuronectes americanus) FOOD CHAIN

The output from this task is a functioning food web model of the New Bedford area for the three important marine organisms of the affected eocsystem ready for calibration.

3.7.3 Task 3 - Preliminary Calibration of the Food Web Model

The next step in model application to the New Bedford area is model calibration on the basis of existing information. The intent is to calibrate the model with observed data preparatory to a detailed calibration with 1984-85 data to demonstrate credibility of the analysis. The calibrated model can also be used as a diagnostic tool to indicate the relative importance of the various physical locations and ecosystem pathways to PCB and copper contamination of the species of interest. Ultimately, the calibrated model is used to assess the effectiveness of remedial activities.

The available database as reviewed in Task 1 will be used to select information whereby both necessary biological data and required physico-chemical measurements (water column and sediment PCB and copper concentrations) are simultaneously available. If such comparable data, particularly water column contaminant concentrations, are not directly available, estimates will be required by physico-chemical modeling means. Water column contaminant concentrations together with sediment concentrations serve as the driving forces to determine the distribution of PCB and copper in the biotic sector of the ecosystem. For each of the selected prime organisms, respiration rates, growth rates assimilation efficiencies, and excretion rates are then assigned in order to calculate the PCB/heavy metal body burden associated with each food web compartment.

Calculated organism contaminant concentration values are then compared with observed data and model adjustment performed as required. It is proposed that whole body PCB and copper concentration values will be calculated and converted to edible fraction and/or viscera values, if necessary, by using known relationships.

The foregoing approach will be repeated for each of the three selected organisms of importance in the New Bedford area and their associated food webs. Various homologous groupings of PCB isomers will be tracked in this manner. In addition, copper will be considered in the analysis.

Once the model has been calibrated for the study area, it serves as a diagnostic model that aids in the assessment of the environmental dynamics and transport mechanisms of PCB and copper. The biological model can be used to attribute the components of contaminant in the principal species and their prey to different pathways of contaminant transfer. This application is illustrated in Figure 3.7.6 for PCB and striped bass in the Hudson River. The upper graph shows the calculated and observed PCB body concentration in the striped bass as a function of age, where the oscillations are a result of the annual migration of the adult striped bass between the river and coastal waters. The portion of this body burden which is attributed to feeding on zooplankton, small fish, and direct uptake from water is shown in the lower graphs of the diagram. A similar approach is used to assess the effect of bed sediment sources on PCB migration through the food web and fishery. Ultimately, by calculating and/or specifying appropriate model inputs such as the ambient concentraiton of PCB in the water column and sediments, the impact of remedial cleanup actions can be ascertained.

It has been noted that specific physico-chemical information, namely water column (dissolved and particulate) and sediment PCB and copper concentration values are required for the biological analysis. It is most desirable that these data are available from direct measurements obtained during the same general time period as the biological monitoring. If such data, particularly in the water column, are lacking, however, for much of the available biological database, estimates must be made.

3.7.4 Task 4 - Evaluation of the 1984-85 Field and Laboratory Data and Detailed Calibration of the Food Web Model

The preliminary calibration of the model (Task 3) is essentially a range-finding procedure in which a set of parameter values is established consistent with the existing database. However, the limitations of that database in terms of the number and quality of the samples preclude an assessment of the validity of the parameter values chosen. The 1984-85 data collected as part of this project will provide the information needed to refine the model. Task 4 consists of an intensive evaluation of this data and the further calibration of the model. It is essentially a repetition of the technical procedures described for Tasks 1 and 3, but with a more intensive effort reflecting the detailed database collected during the field program of 1984-85. As in Task 1, biological data will be segregated by species of interest, trophic level and food web components and spatially displayed as appropriate. The relationships established previously in Task 1 with available

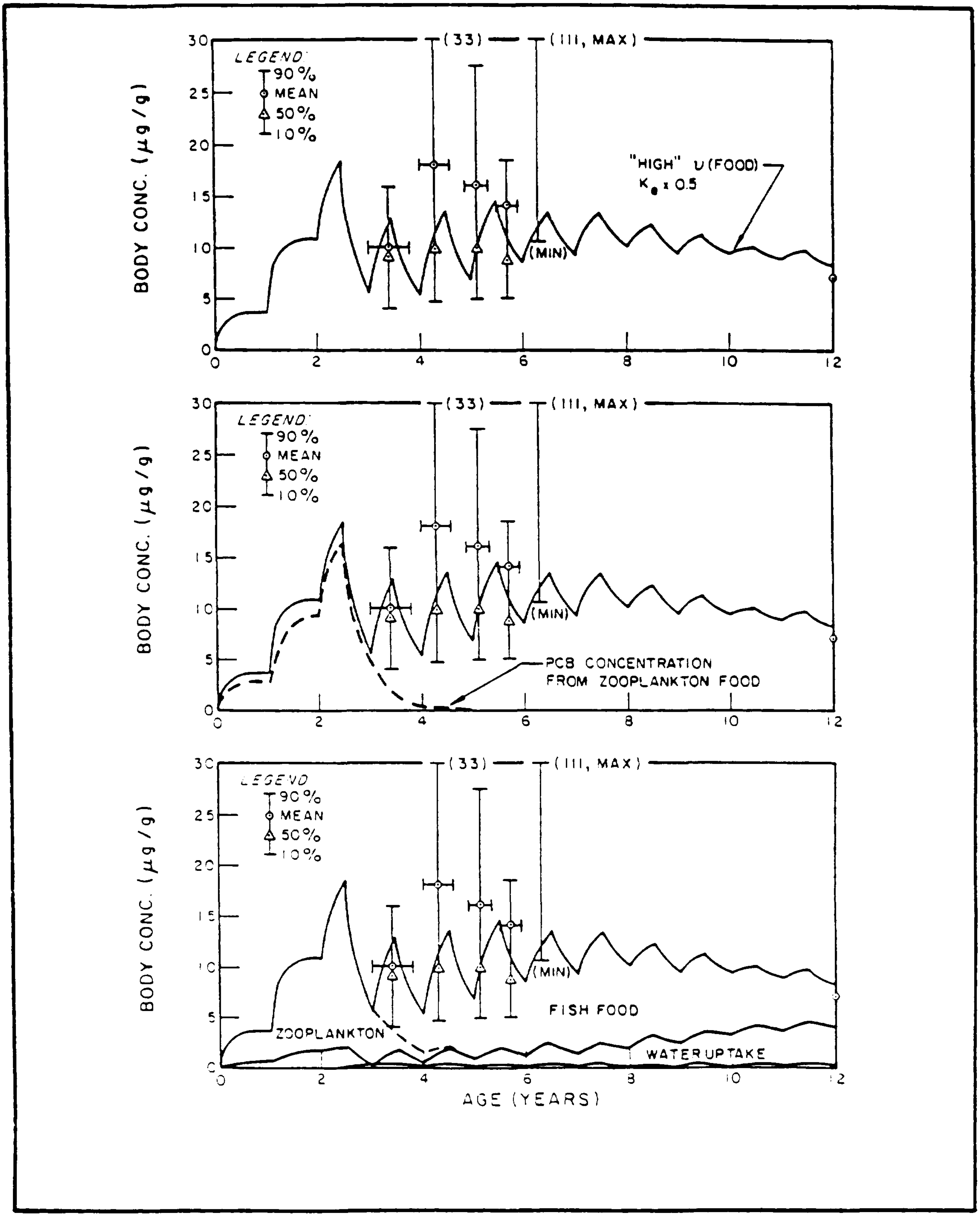


FIGURE 3.7.6. COMPONENTS OF PCB CONCENTRATION IN STRIPED BASS (Morone saxatilis)

data (spatial organism PCB/heavy metal concentrations, organism body contaminant concentration and weight, contaminant concentration factors, etc.) will be expanded and better defined with the new data set.

The preliminary calibrated food web model will then be applied to the 1984-85 biological data. Observed water column and sediment PCB/heavy metal concentration values in the various spatial segments will be input to the biological model for each of the selected species and associated food web of concern. The contaminant concentration distributions in the food web will be calculated and compared with observed data. The higher temporal and spatial resolution of the 1984-85 data relative to the previous data will require a detailed calibration which will yield a more accurate final model. The calibration procedure will be performed for each PCB homologous grouping and copper and for each selected principal organism and its food chain. Model refinements will be made as appropriate.

The output from this task is a calibrated food web model for PCBs and copper in each of the three selected species of interest. The model is available for application to determine the effectiveness of the various remedial actions on lowering PCB and copper body concentraitons in the selected organisms.

3.7.5 Task 5 - Evaluation of Effectiveness of Remedial Action

The calibrated food web model is now applied to assess the consequences of various types of remedial cleanup actions on PCBs and copper in the selected organisms. As during the initial calibration procedure, physico-chemical PCB and copper information is required to drive the biological model. In this case, the required information is projected by the detailed physico-chemical modeling work. It is anticipated that changes in the existing distribution of PCBs and copper in the New Bedford area sediments and water column will be projected with the physico-chemical model for various types of remedial action. The results of these projections are input to the biological model and the response of the food webs and the selected primary organisms are calculated. In this manner, the loop is closed between remedial activity and resulting biological effectiveness.

It is anticipated that a no-action condition would also be investigated under this task. In this circumstance, PCB and copper concentration values are projected with time from present conditions in accordance with sediment transport, burial, any volatilization loss, etc. These time variable distributions are then input to the dynamic food web model to calculate the corresponding changes in the selected biota.

It is recognized that much detailed work is to be accomplished by the physico-chemical modeling analysis and that projections for the effect of remedial actions are likely to come toward the end of the project schedule. In order to facilitate the biological assessment work, however, and assure compliance with the project timetable, estimated sediment and water column PCB distributions may be used for the biological evaluations in advance of final physico-chemical model projections. A wide variety of alternatives can be calculated by the computerized model. In this procedure, beginning around project month fourteen, various scenarios of PCB and copper levels in sediment and water column as may result from various types of remedial action would be specified. Sufficient ranges of values and spatial variability would be considered in order to bound the range of probable values resulting from various remedial actions. The food web model would then be used to calculate the resulting impact on the principal organisms. As final information becomes available from the physico-chemical modeling on refined estimates of the effect of remedial actions on contaminant distributions, the various scenarios previously run for the biological analysis will be refined and used to provide estimates of associated biological effectiveness. A similar procedure may be used for the no-action alternative whereby various waterway and sediment depuration rates are assumed and biological calculations performed accordingly.

Results from this task will be presented in a format similar to that used previously for the biological analysis of the PCB problem in the Hudson River as illustrated in Figures 3.7.7 and 3.7.8. In the first diagram, the PCB concentration calculated in fish less than 300 mm (a compartment in the striped bass food web) is shown as a function of location in the Hudson River Estuary from the Battery in New York City. Two cases are shown: the existing condition from model calibration, and a projection for a dissolved PCB water column concentration of 0.01 μg/l.

Figure 3.7.8 shows projected changes in the PCB body concentrations with time for the top predator of interest in the Hudson Estuary, the striped bass. The diagrams show calculated fish PCB body concentrations for existing conditions and two levels of excretion rates for sensitivity purposes. Also shown on each diagram are changes in body concentration for fish of various ages if the dissolved PCB concentration in the estuary water column decreases by a factor of five. The annual variability shown

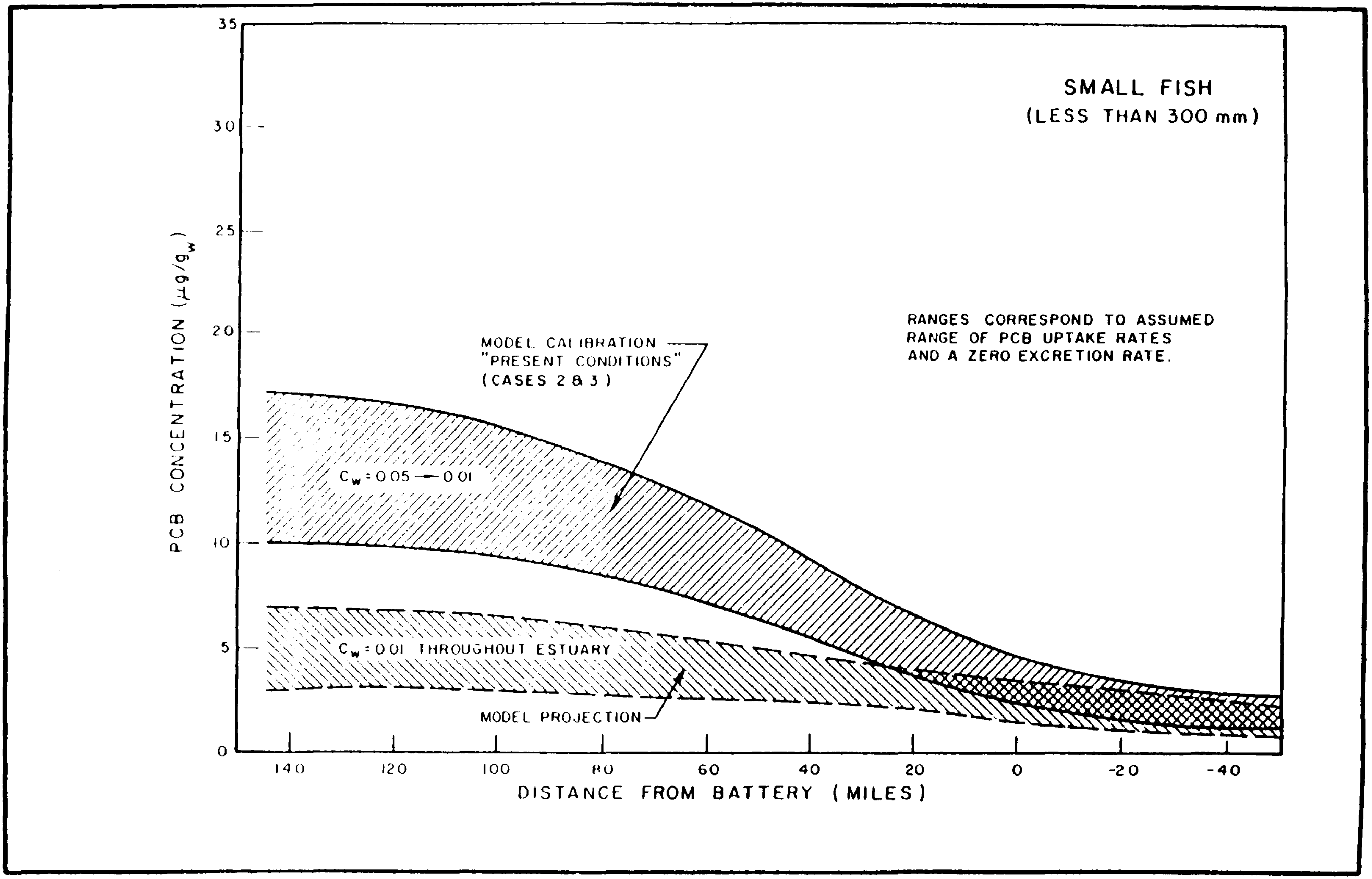


FIGURE 3.7.7. FOOD WEB MODEL PROJECTION, SMALL FISH

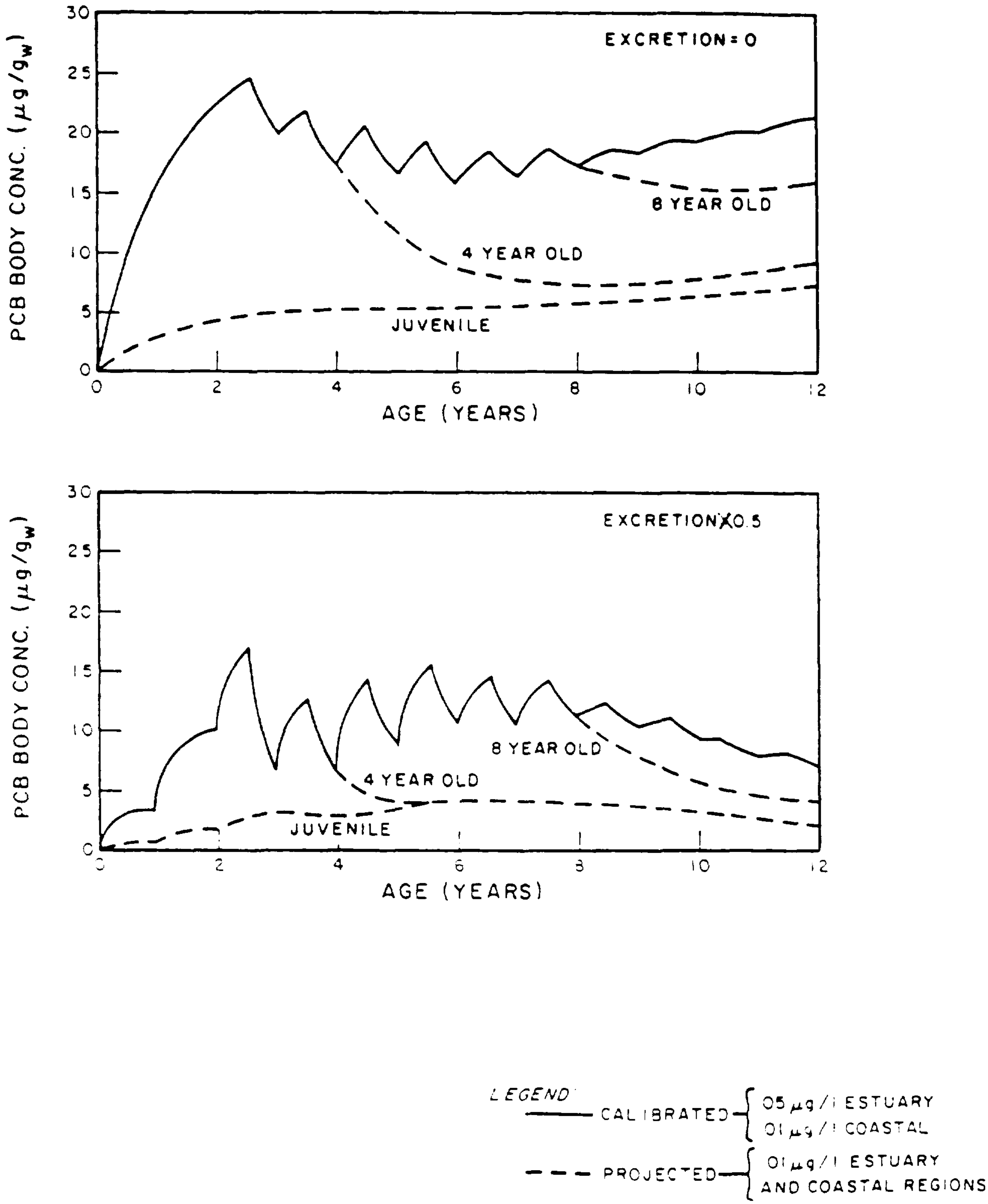


FIGURE 3.7.8. PROJECTED RESPONSE OF DIFFERENT AGE STRIPED BASS TO A FIVE-FOLD DECREASE IN THE ESTUARY PCB WATER AND FOOD CONCENTRATIONS.

for existing conditions is due to the migratory habits of the striped bass within areas of differing PCB concentrations. Such variability does not appear in the projections as the estuary PCB concentrations and the coastal value were assumed to be equal.

The outputs from this task are estimates of the effectiveness of various types and levels (extent) of remedial contaminant cleanup actions in the New Bedford area on resulting PCB/heavy metal body concentrations in the selected organisms.

3.7.6 Task 6 - Reporting and Documentation of Analysis

It is proposed that a comprehensive Final Report be provided at the conclusion of the work to document all evaluations. The report will present detailed conclusions and any appropriate recommendations, describe data evaluations, the basis of analyses, calibration procedures, assessment of remedial actions and individual source impacts.

It is also expected that a number of meetings with project personnel will occur for coordination and reporting purposes. Such meetings may be held on a project milestone basis such as follows: project initiation, completion of evaluation of existing data, completion of preliminary calibration, completion of evaluation of 1984-85 data and detailed model calibration, and evaluation of remedial actions.

3.8 DATA MANAGEMENT

3.8.1 Description of Existing Database

Data management activities in this project deal with both historical and newly collected data. This section presents a brief review of available historical data, and the following two sections describe procedures to be followed regarding new data.

Past studies of PCB and metals contamination in the Acushnet estuary have been reviewed, and salient data abstracted, by Metcalf and Eddy. These data have been used by M&E as the basis for their report to EPA entitled "Acushnet Estuary PCBs Data Management Final Report". These data have been acquired from M&E for use as one input in the design of Battelle's sampling plan.

Data received from M&E consist of 2,690 records of harbor sediments, 159 records of water column data, 35 records from treatment plant effluents, and 1,180 records of aquatic biota data. This collection is presently being managed through use of the Datatrieve data management system (a Digital Equipment Corporation product) on one of Battelle's VAX 11/780 systems in its Computer Center in Columbus, Ohio. Each record contains fields of data describing the type, source, location, date, and time of each analyzed sample. Additionally, each record contains information regarding the identification of the measured parameter, its concentration, and the laboratory and study which led to its collection.

Through interactive access to this database from the New England Laboratory, the data have been used to answer questions dealing with the number, type, and distribution of sediment and water column samples as a function of the occurence and concentration of metals and PCBs. While the data are historical in nature, they do form a valuable input to our sampling plan, and also lend perspective regarding techniques that will be required in the management of new data.

3.8.2 Information System Design

Biological, chemical, and other data collected in the work will be processed through use of an information management system. The central hardware element of this system is a DEC VAX 11/780 computer, located in the Battelle Columbus Laboratories (BCL) Computer Center in Columbus, Ohio. It will be accessed through a 9.6Kb synchronous, multiplexed line from the New England Laboratory. The BCL facility is also accessible via the Tymnet packet communications network on a dial-up basis, and can be made available for access to project reports or other management products by NUS personnel, if desired. Key software elements to be used include the DEC VAX-11 Datatrieve data management system (and possibly the BASIS-DM database management system, as described below), DEC VAX 11 TDMS terminal data management system (for transaction processing), Naitonal Oceanographic Data Center (NODC) map projection subroutines, Precision Visual's DI-3000 graphics software, and DEC Electronic Mail. Printer, plotter, and terminal facilities will be made available at the New England Laboratory. A smaller VAX system will also be available at that laboratory in the near future for use in local tape processing, graphic output control, initial staging of programs, data, and task-related correspondence.

The BCL computer center houses several VAX 11/780 and mainframe CDC computers. These and other hardware components are schematically represented in

Figure 3.8.1 to indicate the backup capacity and task expansion capacity that is available for this work, as well as the distribution of components and access techniques.

The Datatrieve data management system is the basic software element used for management of data. All Datatrieve functions are available to the programmer through standard high level program calls and to the non-programmer through a well-designed English language interface.

The TDMS terminal data management system provides video terminal-based transaction forms support in conjunction with Datatrieve. As TDMS is also a Digital product, it is designed to match and take maximum advantage of Datatrieve functionality. TDMS will be used to design forms containing all the data fields of each data record used in this work.

Datatrieve is a data management system, as opposed to a database management system. It is expected that characteristics of this software are adequate for this work. It provides for dynamic file linking, derived fields, flexible domain definitions, file restructuring, and other needed capabilities. Should there be a need for even more sophisticated data management and screen handling capabilities, however, the BASIS-DM database management system will also be available for use with this work. BASIS-DM is a sophisticated, dictionary-driven system that is a product of Battelle's Software Product Center. Fully designed, supported, and made available on BCL's VAX computer systems, BASIS-DM supports the principal database model needed for this type of work - the relational model. It serves not only as a sophisticated database management tool, but illustrates another aspect of Battelle's depth of capabilities and experience in the area of information system design and use.

NODC map projection subroutines and associated land mass digitizations provide the basic plotting capability needed here. They will be used for quality control and data analysis products. DI-3000 graphic subroutines will be used to generate graphic displays of data processed through the NODC map projection routines or other non-map related products.

The electronic mail software available on the VAX will allow for complete documentation of transmittal letters, general correspondence, and other communications that relate to this task.

The distributed nature of this sytem takes maximum advantage of personnel locations and hardware/software availability. In this distributed environment, all programming activities will be carried out in Columbus, Ohio, and all production use of

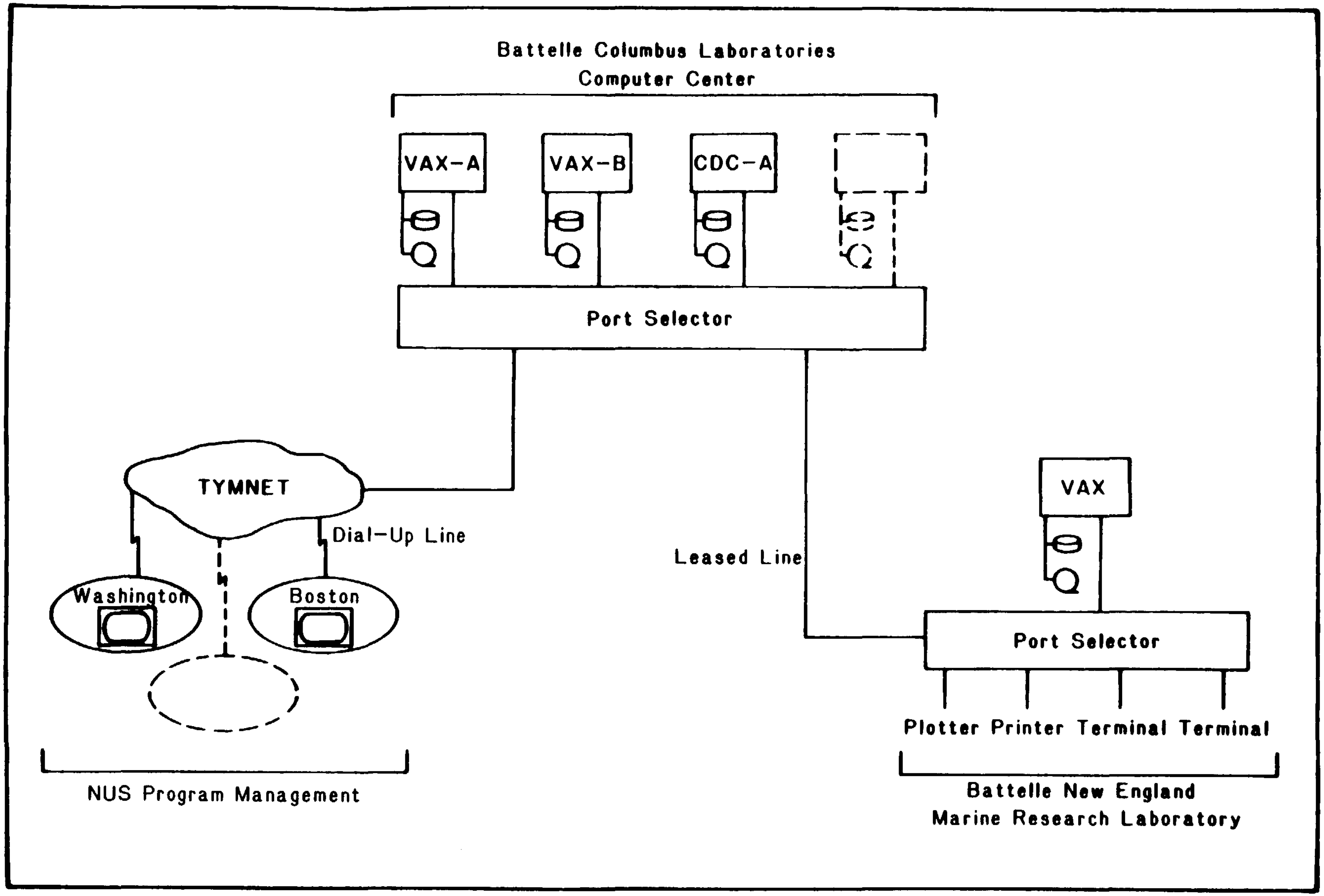


Figure 3.8.1. Schematic Hardware Configuration of Battelle Information Management System.

the system will be carried out in Duxbury, Massachusetts. While this section has dealt with the components that make up the system, the next section describes how it will be used.

3.8.3 Data Management Operations

The information management system described in Section 3.8.2 provides the framework that will be used in processing the data collected in this project, and which also allows the retrieval of data for use in reports, in statistical analyses, in models, and in other analyses.

Data that are to be used for these purposes will be input to the system under quality-controlled transaction processing conditions. Data will be interactively keyed in response to screen-oriented forms. As the data are entered, individual items will be range-checked, code-checked, or processed by special algorithms that evaluate the reasonableness of the data. Items failing to pass this quality control screening will be corrected during entry. Data received on tape by Battelle from the EPA Contract Lab system will be input to the Battelle information system through the VAX 11/780 computer at the BCL Computer Center in Columbus, Ohio, until the smaller VAX is available at Battelle New England.

After entry, the data form a part of the project database. Additional quality control checks are then run comparing individual items with others in the database. As one example, time-distance checks on cruise tracks can reveal cases where data have passed a range check, yet give unreasonable ship speeds. This might result from accidental reversal of two-digit converting a U.S.G.S. grid X coordinate from 0343 to 0334, for example, or a time of day from 1221 hrs to 1212 hrs. Such errors, while passing range checks, may produce unreasonable values for calculated ship's speed. By further examination of all data items used in the calculation, and comparison of entered values with labor field notes, the errant item(s) are often found, resolving the problem.

Errors found during this after-entry phase are corrected through use of the same interactive access forms used during entry. Once entered and quality controlled, the database is ready for use.

Non-programmer project personnel will access the data using the standard Datatrieve interface. Through Boolean logic commands, what-if and other one-shot questions will be answered. Elaborate queries and report-oriented queries can also be made by non-programmer personnel. Many queries will become standardized with time, and these can be saved as "procedures", allowing their execution through typing only a simple command. Some examples of standardized reports are database or field operation summary reports, analyses of the data that are periodically rerun to take advantage of a larger volume of data, and the like.

Programming assistance will be available to project personnel for other data manipulation needs. Some of these will occur in the design of more sophisticated quality control schemes. The calculation of average ship's speed between stations cited above is one example. The output of this product could be a colored cruise track plot where failed interstation segments were colored red, and others colored green, for example. A number of data analyses will be of a customized type, not available as part of a graphics or statistics package or other analysis available on a "canned" basis. They may result in tabular arrays of processed data, or they may be graphical portrayals. In either event, programming assistance will be available for product development.

The modeling studies constitute a third analytical use of the project database. Either Datatrieve or customized interfaces will be established between the database and each model. In some instances, the Datatrieve-based selection of a subset of the overall database will be appropriate. In others, the programmer-level interface to Datatrieve functions will be used to prepare the appropriate subset of the overall database for use with models.

This section has presented a description of the use of Battelle's information system for the entry, quality control, maintenance, retrieval, and analysis of the data used in this project. All project personnel will have easy access to the data through either leased line or deal-up techniques. The data can be used for analytical as well as project management activities by programmer and non-programmer personnel, and will form a key element in the successful performance of this work.

3.9 REPORTS

3.9.1 Final Report

A Draft Final Report will be submitted to NUS Corp. on or before January 3, 1986. This report will contain a detailed description of all tasks performed and work accomplished. In addition, it will contain a detailed description, interpretation, and discussion of the output of the physical/chemical model and the food-chain model. All the items described under Objectives (Section 2.1) and Data Usage (Section 2.4) of this Work Plan will be discussed in detail. Following formal review by NUS and EPA, the Draft Final Report will be revised, incorporating improvements recommended by the reviewers. A revised Final Report will be submitted to NUS on or before January 31, 1986. At the end of the project, a computer tape containing all data accumulated and managed in this project will be supplied to NUS.

3.9.2 Interim Reports

Interim Status/Progress Reports will be submitted to NUS at approximately quarterly intervals. These reports will be issued at the time of or shortly after periodic working meetings of the modeling team, to which the sponsor's representatives will be invited.

The Interim Reports will cover all work performed during the previous quarter. Each report will summarize work accomplished during the previous quarter in relation to the schedule of tasks as outlined in the PERT (Figure 4.2.2), problems encountered and solutions, and preliminary conclusions to date. In addition, the reports will include an estimate of the work to be performed during the subsequent quarter and how that projection matches with the scheduling plan. Finally, there will be a cost summary which will include cumulative costs to date, costs for the current reporting quarter, anticipated costs for the next quarter, relationship between costs incurred and percent of work completed, and estimates of costs expected to complete the work.

3.10 PROPOSAL SUBMITTED TO BATTELLE LABORATORIES BY WOODS HOLE OCEANOGRAPHIC INSTITUTION

Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: (617) 548-1400
Telex: 951679

May 17, 1984

Battelle Laboratories
Drawer AH
Washington, Street
Duxbury, MA 02332

Dear Sirs:

On behalf of Robert C. Beardsley and Richard Limeburner the Woods Hole Oceanographic Institution submits herewith three copies of a research proposal entitled, "BUZZARDS BAY CIRCULATION STUDY".

Sincerely,

Maurice J. Tavares
Sponsored Programs
Administrator

MJT/lcs

Enclosures

W.H.O.I. Proposal 3614

PROPOSAL SUBMITTED TO

BATTELLE LABORATORIES
Drawer AH
Washington Street
Duxbury, Massachusetts 02332

by the

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

entitled

BUZZARDS BAY CIRCULATION STUDY

Proposed Starting Date: 1 June 1984

Proposed Duration: 18 months

Amount Requested: $138,702

Endorsements:

Robert C Beardsley

Robert C. Beardsley
Co-Principal Investigator
Senior Scientist
Dept. of Physical Oceanography
(617) 548-1400, ext. 2536

Richard Limeburner (RCB)

Richard Limeburner
Co-Principal Investigator
Research Associate
Dept. of Physical Oceanography
(617) 548-1400, ext. 2539

N.P. Fofonoff

N. P. Fofonoff, Chairman
Dept. of Physical Oceanography
(617) 548-1400, ext. 2487

Gary B. Walker
Controller
(617) ~~548~~-1400, ext. 2362

Derek W. Spencer

Derek W. Spencer
Associate Director for Research
(617) 548-1400, ext. 2244

Date: 17 May 1984

W.H.O.I. Proposal Serial No. 3614

BUZZARDS BAY CIRCULATION STUDY

by
R. Beardsley, R. Limeburner, R. Signell
Physical Oceanography Department
Woods Hole Oceanographic Institution

We propose to conduct a three component experiment to study the tidal and subtidal circulation and dispersion in Buzzards Bay. The three components include a Lagrangian study to measure the temporal and spatial structure of Lagrangian currents and particle dispersion near New Bedford Harbor and within Buzzards Bay, a moored array experiment conducted across the mouth of Buzzards Bay to observe currents and inflow into the bay and monitor sea level fluctuations within the bay, and a series of hydrographic surveys to measure water stratification during the drifter and moored array experiments (Fig. 1). The recent hydrographic work reported by Rosenfeld, Signell and Gawarkiewicz (1984) shows that the stratification within the bay varies from a highly-stratified state in summer to a locally well-mixed regime in winter (Figs. 2 and 3). Field measurements reported by Grant and others (personal communication) suggest that the sediment resuspension in the bay is primarily due to the combined effect of surface waves, tidal currents and wind-driven currents during storms. For these reasons, we propose to conduct the full experiment from late summer (August, 1984) to early winter (January, 1985), to see how the subtidal circulation and particle dispersion vary with the seasonal changes in ambient stratification and wind-forcing.

We will now describe the three components in more detail.

A. Drifter Component

We propose to purchase seven Sea Data LORAN-C drifting buoys and conduct a series of reseeding experiments to measure Lagrangian currents in different regions of the Bay. Based on a design initially developed at WHOI, the Sea Data buoy used an automatic LORAN-C receiver to locate the buoy and a HF radio

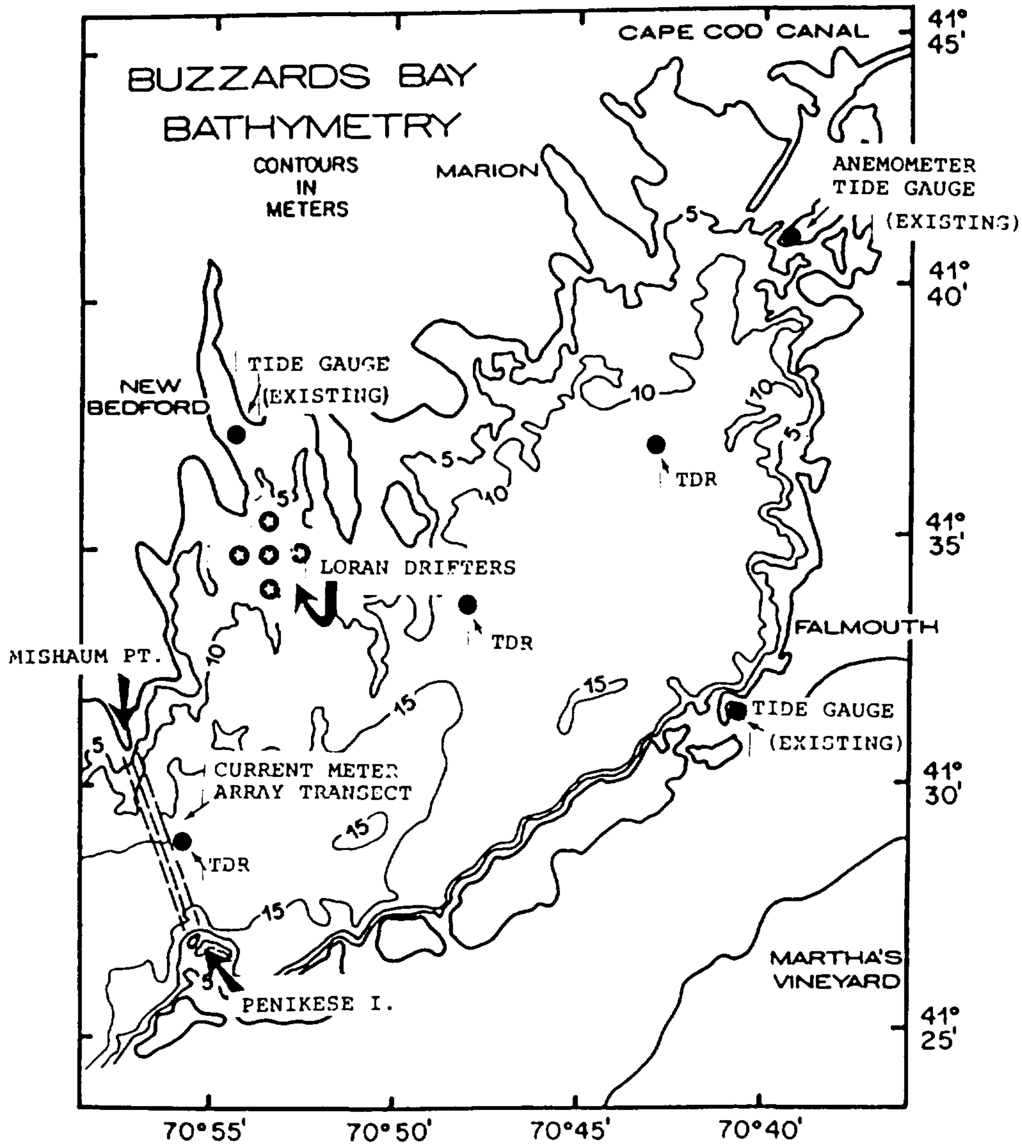


Figure 1: Proposed and existing equipment locations.

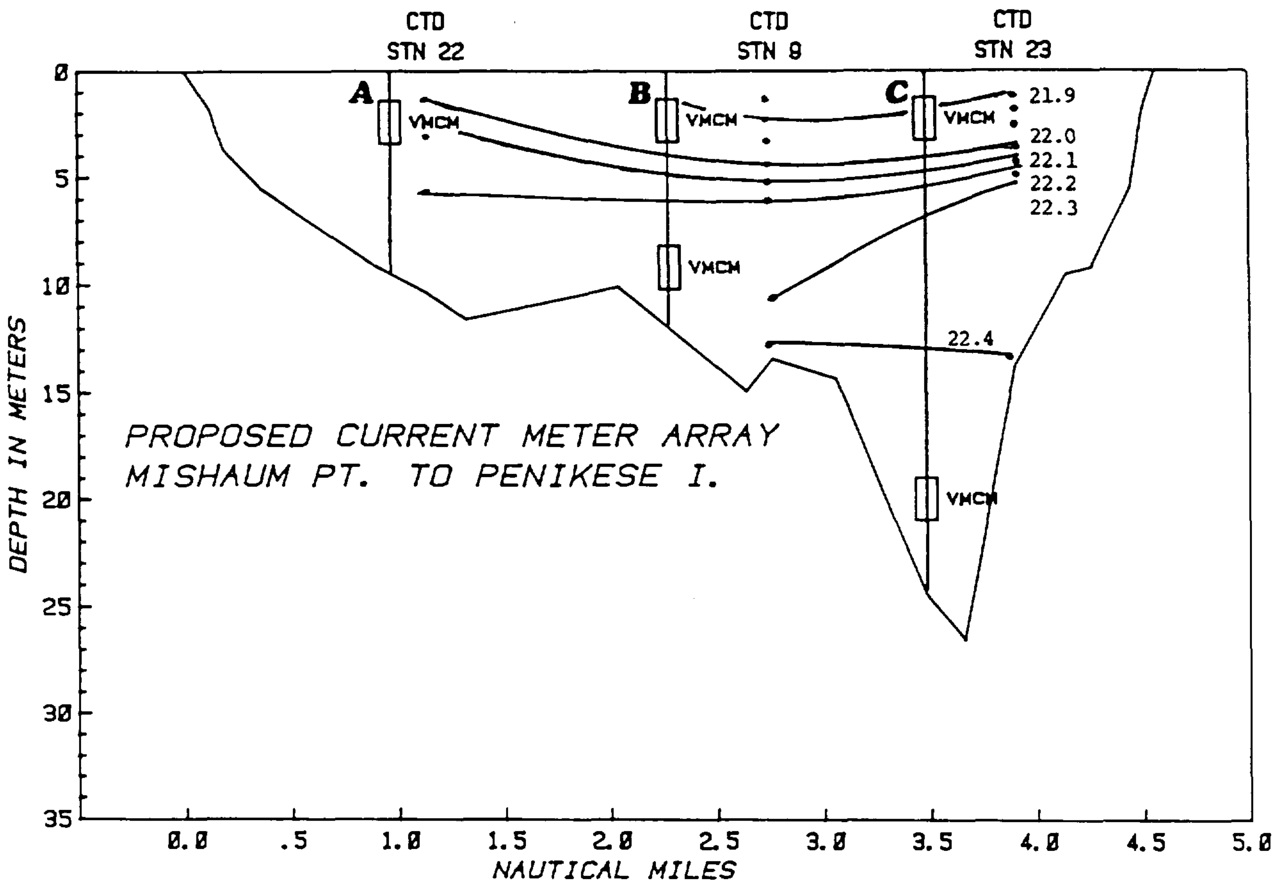


Figure 2: Vertical section of Sigma-T showing stratification: July 30, 1982.

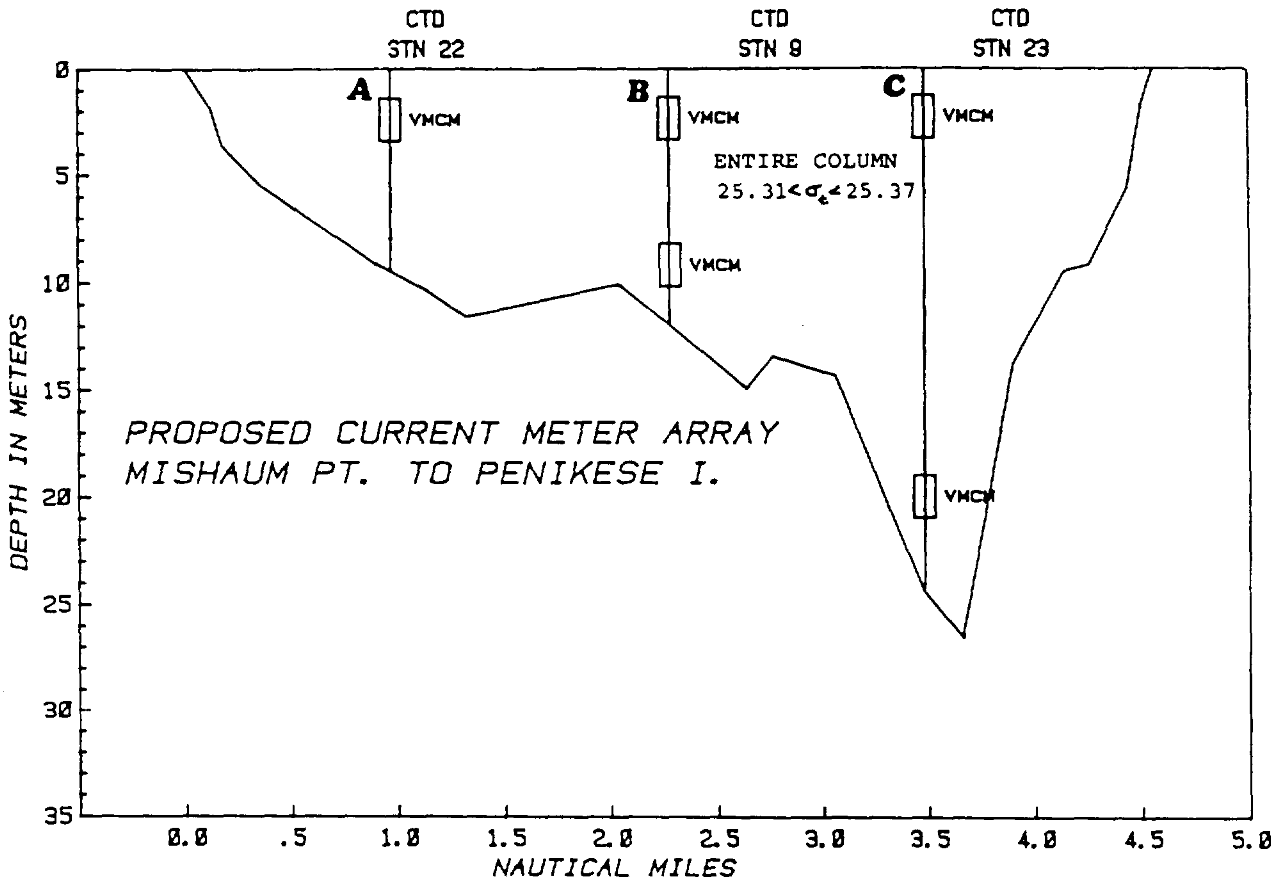


Figure 3: Vertical section of Sigma-T showing well mixed winter condition: January 14, 1982.

link to transmit the position data to a shore station. In normal operation, a buoy determines its LORAN-C fixes once or twice an hour and transmits the position and time information of fixes over the last five days (for redundancy) to a short station once a day. A buoy also has a relocate mode which can be activated at sea by a special radio command to allow easy retrieval. We thus propose to conduct a series of reseeding experiments in which the buoys are tracked until they drift outside the study area then retrieved and reset in the original positions. This sequence is then repeated several times until enough individual drifter realizations have been obtained to allow a statistically significant flow characterization. The relocate mode allows the buoys to be reused in many such experiments, and thus these reseeding experiments are a very cost-effective approach to study the spatial structure of flow in a region of complex topography.

The drifters can be easily deployed and recovered using the R/V ASTERIAS. The shore station has already been built and much of the software for the statistical analysis of the drifter data is available for the WHOI SOFAR Float Program directed by P. Richardson. While the actual design and execution of a drifter experiment will depend on the flow structures observed, we estimate that on average we will need to recover and reset the drifter every three days, thus we have requested twelve days of shiptime for a 30-day experiment. We have also requested a portable transmitter to allow reprogramming the buoys at sea and spare drogues and miscellaneous hardware.

B. Moored Array Component

We propose to deploy a moored array of current meters and temperature/pressure recorders to study the tidal and subtidal flow into the bay and the response of the bay to strong wind forcing. The array consists of five vector measuring current meters (VMCMs) deployed on three surface moorings (labelled A, B, C in Figure 2), and four temperature/pressure recorders (TDRs) located at selected positions within the bay. The TDRs will augment the existing tide stations to provide a good spatial array to monitor tidal and low-frequency surface elevation fluctuations throughout the entire bay. This information provides a good quantitative check on the temporal variations of net flux into the bay estimated directly from the current meter data, and both direct sea level and current observations will be essential to understand the response of the bay to strong local wind forcing and offshore forcing and for adjustment and verification of numerical circulation models. Local wind data will be collected from two existing sites.

The array can be prepared at Woods Hole and deployed and recovered using the R/V ASTERIAS. A conservative estimate of 12 days of shiptime are requested for the deployment and recovery operations and possible servicing during the deployment period. The VMCMs provide accurate current measurements even when deployed on surface moorings (as is planned here) and also record temperature. A deployment period of five months is proposed.

C. Hydrographic Component

It is important to know the water stratification during the drifter and moored array experiments, so a series of short (1 to 2 day) hydrographic surveys are planned during those experiments. These surveys would be conducted with a Neil Brown CTD equipped with a light transmissometer and can be conducted using the R/V ASTERIAS. We propose to conduct three surveys during the moored array experiment (after deployment, midway, and before recovery) and two short surveys during a 15-to-30 day drifter experiment.

It should be clear that the present lack of direct current observations in Buzzards Bay prevent any conclusive statements about circulation and dispersion within the bay. For this reason, we feel it is most important to begin to make direct current measurements. While it would be best to conduct both drifter and moored array experiments simultaneously, it is most important in our view to start with a drifter program as soon as possible. This would provide critical scientific information on Lagrangian currents near New Bedford Harbor and also valuable experience on how to use a relatively new observational tool to study circulation in a new environment. A series of drifter experiments conducted in different regions of the bay could also help refine the design for the moored array experiment.

Due to the significant seasonal change in stratification and wind forcing, the complete (three component) experiment should be conducted during both summer and winter periods. A tentative schedule is shown in Figure 4.

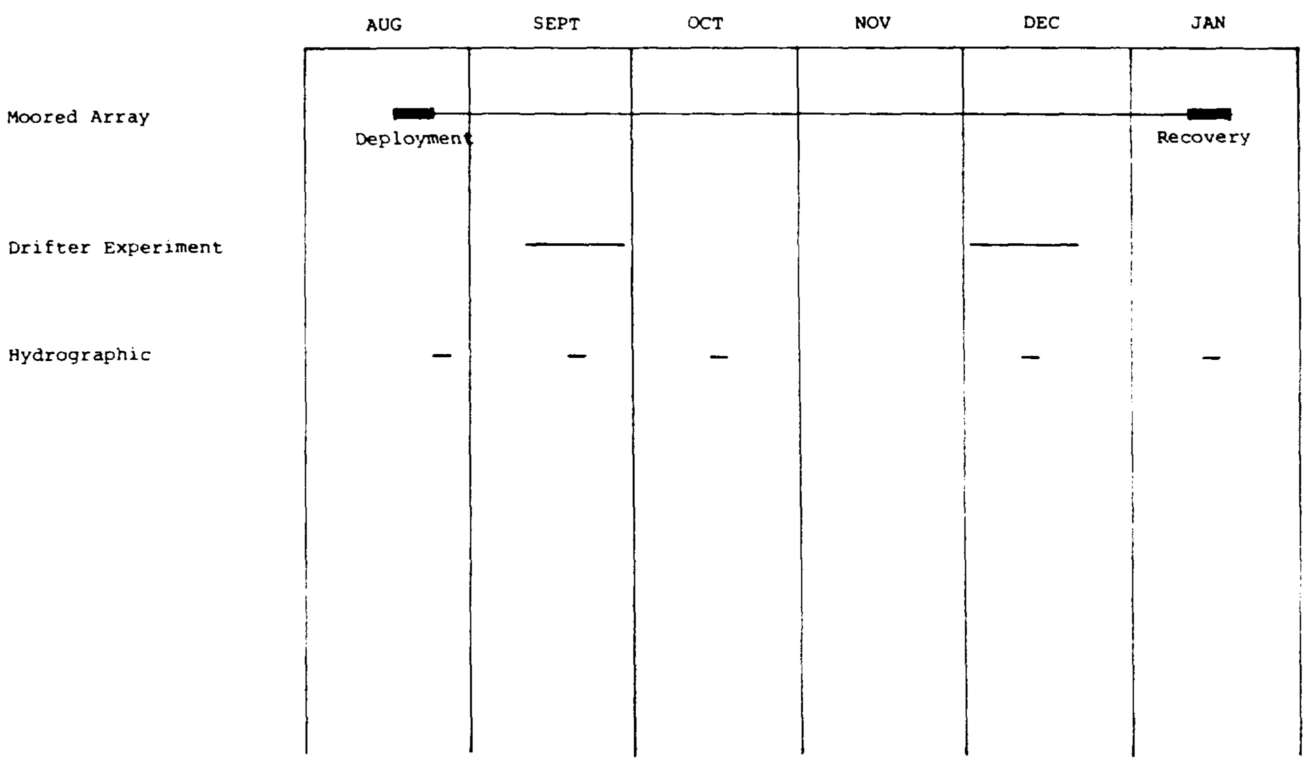


Figure 4: Tentative experimental schedule.

List of data products that will be delivered to Battelle

1. Moored Array (after recovery):
   a. Edited 1 hour average current meter data
   b. Edited wind data for that period

2. Drifter (after each experiment):
   a. Listings of time/position time seires for each drifter
   b. Plots of trajectories

3. Hydrography (after each survey):
   a. Standard station listings
   b. Profile plots

Reference

Rosenfeld, L. K., R. P. Signell and G. G. Gawarkiewicz, 1984. Hydrographic study of Buzzards Bay, 1982 - 1983. Woods Hole Oceanographic Institution Technical Report WHOI-84-5, 134 pp.

Biographical Sketch and Recent Publications of Co-Principal Investigators

Robert C. Beardsley

Born January 28, 1942. B.S., Massachusetts Institute of Technology, 1964; Ph.D., Massachusetts Institute of Technology, 1968. Assistant Professor of Oceanography, 1967-72; Associate Professor of Oceanography, 1972-1975; Lecturer, 1975-77, Department of Meteorology, Massachusetts Institute of Technology. Student Fellow, Geophysical Fluid Dynamics Seminar, 1966; Associate Scientist, 1975-81; Senior Scientist, 1981--, Woods Hole Oceanographic Institution.

Recent Publications

Winant, C. D. and R. C. Beardsley, 1979.
A comparison of some shallow wind-driven currents. Journal of Physical Oceanography, 9, 218-220.

Beardsley, R. C. and C. D. Winant, 1979.
On the mean circulation in the Mid-Atlantic Bight. Journal of Physical Oceanography, 9, 612-619.

Vermersch, J. A., R. C. Beardsley and W. S. Brown, 1979.
Winter circulation in the western Gulf of Maine: Part 2. Current and pressure observations. Journal of Physical Oceanography, 9, 768-784.

Beardsley, Robert C., Kim D. Saunders, Alex C. Warn-Varnas and John M. Harding, 1979.
An experimental and numerical study of the secular spin-up of a thermally stratified rotating fluid. Journal of Fluid Mechanics, 93, part 1, 161-184.

Ou, Hsien Wang, and Robert C. Beardsley, 1980.
On the propagation of free topographic Rossby Waves near continental margins. Part 2: Numerical model. Journal of Physical Oceanography, 10, 1323-1339.

Beardsley, Robert C. and William C. Boicourt, 1981.
On estuarine and continental-shelf circulation in the Middle Atlantic Bight. In: Evolution of Physical Oceanography, Scientific Surveys in Honor of Henry Stommel; Bruce A. Warren and Carl Wunsch, editors; The MIT Press, Cambridge, Massachusetts; pp. 198-233.

Beardsley, Robert C. and Dale B. Haidvogel, 1981.
Model studies of the wind-driven transient circulation in the Middle Atlantic Bight, Part 1: Adiabatic boundary conditions. Journal of Physical Oceanography, 11, 355-375.

Beardsley, R. C., W. Boicourt, L. C. Huff, J. R. McCullough and J. Scott, 1981. CMICE 76: A current meter intercomparison experiment conducted off Long Island in February-March 1976. Deep-Sea Research, 28, 1577-1603.

Ou, Hsien Wang, Robert C. Beardsley, Dennis Mayer, William C. Boicourt and Bradford Butman, 1981.
An analysis of subtidal current fluctuations in the Middle Atlantic Bight. Journal of Physical Oceanography, 11, 1383-1392.

Butman, B., R. C. Beardsley, B. Magnell, D. Frye, J. A. Vermersch, R. Schlitz, R. Limeburner, W. R. Wright and M. A. Noble, 1982.
Recent observations of the mean circulation on Georges Bank. Journal of Physical Oceanography, 12, 569-591.

Limeburner, Richard and Robert C. Beardsley, 1982.
The seasonal hydrography and circulation over Nantucket Shoals. Journal of Marine Research, Supplement to 40, 371-406.

Houghton, Robert W., Ronald Schlitz, Robert C. Beardsley, Bradford Butman and J. Lockwood Chamberlin, 1982.
The Middle Atlantic Bight cold pool: Evolution of the temperature structure during summer 1979. Journal of Physical Oceanography, 12, 1019-1029.

Daifuku, Peter R. and Robert C. Beardsley, 1983.
The K1 tide on the continental shelf from Nova Scotia to Cape Hatteras. Journal of Physical Oceanography, 13(1), 3-17.

Ramp, S. R., R. C. Beardsley and R. Legeckis, 1983.
An observation of frontal wave development on a shelf-slope/warm core ring front near the shelf break south of New England. Journal of Physical Oceanography, 13(5), 907-912.

Butman, Bradford, Marlene Noble, David C. Chapman, and Robert C. Beardsley, 1983.
An upper bound for the tidally rectified current at one location on the southern flank of Georges Bank. Journal of Physical Oceanography, 13(8), 1452-1460.

Allen, J. S., R. C. Beardsley, J. O. Blanton, W. Boicourt, B. Butman, L. K. Coachman, A. Huyer, T. H. Kinder, T. C. Royer, J. D. Schumacher, R. L. Smith, W. Sturges and C. Winant, 1983.
Physical oceanography of continental shelves. Reviews of Geophysics and Space Physics, 21(5), 1149-1181.

Limeburner, Richard and Robert C. Beardsley,
Water masses and circulation in the East China Sea. In: The Proceedings of the International Symposium on the Continental Shelf with Special Reference to the East China Sea, April 12-16, 1983, Hangzhou, China, in press.

Beardsley, R. C., R. Limeburner, D. X. Hu, K. T. Le, G. A. Cannon and D. J. Pashinski,
Structure of the Changjiang River plume in the East China Sea during June 1980. In: The Proceedings of the International Symposium on the Continental Shelf with Special Reference to the East China Sea, April 12-16, 1983, Hangzhou, China, in press.

Butman, B. and R. Beardsley,
The physical oceanography of Georges Bank: Introduction and summary. In: Georges Bank, R. H. Backus, editor, The MIT Press, in press.

Butman, Bradford, John W. Loder and Robert C. Beardsley,
The seasonal mean circulation on Georges Bank: Observation and theory. In: Georges Bank, R. H. Backus, editor, the MIT Press, in press.

Butman, Bradford and Robert C. Beardsley,
Long-term observations on the southern flank of Georges Bank: Seasonal cycle of current, temperature, stratification and wind stress. Journal of Physical Oceanography, submitted.

Friehe, Carl A., Robert C. Beardsley, Clinton D. Winant and Jerome P. Dean,
Intercomparison of aircraft and surface buoy meteorological data during CODE-1. Journal of Atmospheric and Oceanic Technology, submitted.

Beardsley, Robert C., David C. Chapman, Kenneth H. Brink, Steven R. Ramp and Ronald Schlitz,
The Nantucket Shoals Flux Experiment (NSFE79), Part 1: A basic description of the current and temperature variability. Journal of Physical Oceanography, submitted.

Richard Limeburner

Born July 23, 1945. B.A., Colgate University, 1968 (economics); M.S., University of Massachusetts, 1975 (marine science); Sc.M., Massachusetts Institute of Technology, 1979 (physical oceanography). Graduate Research Assistant, 1975-79; Visiting Investigator, 1979-81; Research Associate, 1981--, Woods Hole Oceanographic Institution.

Recent Publications and Technical Reports

Limeburner, Richard, 1979.
Hydrography and circulation about Nantucket Shoals. Sc.M. Thesis, Massachusetts Institute of Technology, 113 p.

Limeburner, R. and R. C. Beardsley, 1979.
Hydrographic station data obtained in the vicinity of Nantucket Shoals, May, July, September, 1978. Woods Hole Oceanographic Institution Technical Report WHOI-79-30.

Limeburner, R., R. C. Beardsley and W. Esaias, 1980.
Biological and hydrographic station data obtained in the vicinity of Nantucket Shoals, May 1978 - May 1979. Woods Hole Oceanographic Institution Technical Report WHOI-80-7, 89 p.

Legeckis, R., E. Legg, and R. Limeburner, 1980.
Comparison of polar and geostationary satellite infrared observations of sea surface temperatures in the Gulf of Maine. Remote Sensing of Environment, 9, 339-350.

Limeburner, R. and R. C. Beardsley, 1982.
Hydrographic station data obtained in the East China Sea, June, 1980. Woods Hole Oceanographic Institution Technical Report WHOI-82-10, 15 p. + 144 figures.

Limeburner, R. and R. C. Beardsley, 1982.
The seasonal hydrography and circulation over Nantucket Shoals. Journal of Marine Research, Supplement to 40, 371-406.

Butman, B., R. C. Beardsley, B. Magnell, D. Frye, J. A. Vermersch, R. Schlitz, R. Limeburner, W. R. Wright, and M. A. Noble, 1982.
Recent observations of the mean circulation on Georges Bank. Journal of Physical Oceanography, 12, 569-591.

Limeburner, R. and R. C. Beardsley, 1982.
Hydrographic station data obtained in the East China Sea, August, 1981. Woods Hole Oceanographic Institution Technical Report WHOI-82-39, 11 p. + 63 figures.

Limeburner, R. and R. C. Beardsley, 1982.
Hydrographic station data obtained in the East China Sea, November, 1981. Woods Hole Oceanographic Institution Technical Report WHOI-82-44, 9 p. + 40 figures.

Limeburner, Richard and Robert C. Beardsley,
Water masses and circulation in the East China Sea. In: The Proceedings of the International Symposium on the Continental Shelf with Special Reference to the East China Sea, April 12-16, 1983, Hangzhou, China, in press.

Beardsley, R. C., R. Limeburner, D. X. Hu, K. T. Le, G. A. Cannon and D. J. Pashinski,
Structure of the Changjiang River plume in the East China Sea during June 1980. In: The Proceedings of the International Symposium on the Continental Shelf with Special Reference to the East China Sea, April 12-16, 1983, Hangzhou, China, in press.

Predetermined Rates

Certain costs related to the proposed activity are subject to fixed predetermined rates established by negotiations with the Office of Naval Research and contained in a Negotiation Agreement dated 8 June 1983 for use on all federally sponsored contracts and grants. They are:

	CY 1984	CY 1985
1. General and Administrative Expenses	X	X
2. Laboratory Costs	X	X
3. Employee Benefits	X	X

The budget is based on negotiated rates for calendar years 1984-1985. Budgeted costs for periods beyond 1985 are estimated but will be charged in accordance with any future agreement which may modify the rates.

Laboratory Costs

Laboratory Costs are those costs directly associated with the scientific effort but not readily allocable to individual programs. The majority of the cost is the operating expense of the plant (facilities charge) occupied by research personnel. Other expenses include maintenance of department equipment, salaries of department administration, costs of the research, document and data libraries, and costs of specialized research facilities and equipment.

Costs are allocated as a percentage of direct personnel costs plus related employee benefits. Salaries do not include premium pay.

General and Administrative Expenses

General and Administrative expenses are those costs associated with the administrative aspect of the Institution. They include the Directorate, Controller's Office, Procurement Office, Personnel Office, Mailroom, Shipping and Receiving, Property Office, Vehicle Operations, Security, Stockroom, and Systems and Procedures.

General and Administrative costs are allocable to virtually all Institution activities. It is applied as a percentage of direct salaries plus related employee benefits. Direct salaries do not include premium pay.

SALARY AND RELATED COSTS INFORMATION

TOTAL SALARIES			$ 22,723
Employee Benefit Base:			
44.3 % of $11,882 = $ 5,263			
45.6 % of $10,841 = $ 4,943			
Total Employee Benefits			$ 10,206
TOTAL SALARIES AND EMPLOYEE BENEFITS			$ 32,929
Laboratory Cost:			
Salaries & Employee Benefits	$ 17,146		
Less Premium Pay	($ -)		
27.7 % of	$ 17,146	= $ 4,750	
Salaries & Employee Benefits	$ 15,784		
Less Premium Pay	($ -)		
29.3 % of	$ 15,784	= $ 4,625	
TOTAL LABORATORY COST			$ 9,375
Indirect Cost Base:			
Salaries & Employee Benefits	$ 17,146		
Less Premium Pay	($ -)		
27.2 % of	$ 17,146	= $ 4,664	
Salaries & Employee Benefits	$ 15,784		
Less Premium Pay	($ -)		
26.8 % of	$ 15,784	= $ 4,230	
TOTAL INDIRECT COST			$ 8,894

BUDGET

Buzzards Bay Circulation Study

I. DRIFTER COMPONENT			
A. PERSONNEL			
	1. Research Specialist, Engineer		2 weeks
	2. Research Associate		7 weeks
	TOTAL SALARIES AND BENEFITS		$ 7,190
B. MATERIALS AND SUPPLIES			
	1. 7 SeaData LORAN-C drifting buoys @ $5000/ea	$35,000	
	2. 7 spare drogues @ $250/ea	1,750	
	3. Shore station electronics	1,000	
	4. Transmitter/encoder	1,300	
	TOTAL MATERIALS AND SUPPLIES		39,050
C. OTHER DIRECT COSTS			
	1. Computer Services - VAX-11	4,000	
	2. Graphic Services	2,000	
	3. Publication Costs (technical report)	1,000	
	4. Shiptime: 12 days Asterias @ $280/da	3,360	
	TOTAL OTHER DIRECT COSTS		10,360
D. TOTAL DIRECT COSTS			56,600
E. INDIRECT COSTS			
	1. Laboratory Overhead	1,992	
	2. General and Administrative Costs	1,956	
	TOTAL INDIRECT COSTS		3,948
F. TOTAL INDIRECT AND DIRECT COSTS			$ 60,548
II. HYDROGRAPHIC COMPONENT			
B. MATERIALS AND SUPPLIES			
	1. Ten HP tapes		$ 200
C. OTHER DIRECT COSTS			
	1. Water sample analysis for calibration	$ 400	
	2. CTD insurance	500	
	3. Publication Costs (technical report)	1,000	
	4. Shiptime: 8 days Asterias @ $280/da	2,240	
	TOTAL OTHER DIRECT COSTS		4,140
D. TOTAL DIRECT COSTS			4,340
E. INDIRECT COSTS			
F. TOTAL DIRECT AND INDIRECT COSTS			$ 4,340

III. MOORED ARRAY COMPONENT

A. PERSONNEL

1. Research Specialist, Engineer		6 days
2. Research Associate		6 days
3. Research Assistant		6 days
4. Ten Mooring Technicians		34 weeks
TOTAL SALARIES AND BENEFITS		$ 25,739

B. MATERIALS AND SUPPLIES

1. Materials for preparation of three moorings with surface buoys	$ 6,200	
2. One VMCM Sail Loop system	1,500	
3. Five VMCM turnarounds @ $385/ea	1,925	
4. Five VMCM batteries @ $110/ea	550	
5. Spare sensor set	468	
6. Computer supplies	50	
7. Materials to maintain laboratory equipment	50	
8. Materials to refurbish buoys	480	
9. Stockroom charges	50	
TOTAL MATERIALS AND SUPPLIES		11,273

C. OTHER DIRECT COSTS

1. Computer Services - VAX-11	7,000	
2. Graphic Services	2,000	
3. Publication Costs (technical report)	1,000	
4. Insurance	1,750	
5. Shiptime: Asterias; 9 da @ $280; 2 da @ $315	3,150	
6. Shop Services	414	
7. Communications and Postage	100	
8. Xerox charges	82	
9. Maintenance contracts on terminals	380	
TOTAL OTHER DIRECT COSTS		15,876

D. TOTAL DIRECT COSTS 52,888

E. INDIRECT COSTS

1. Laboratory Overhead	7,383	
2. General and Administrative Costs	6,938	
TOTAL INDIRECT COSTS		14,321

F. TOTAL INDIRECT AND DIRECT COSTS $ 67,209

SUMMARY

A.	TOTAL SALARIES AND BENEFITS	$ 32,929
B.	TOTAL MATERIALS AND SUPPLIES	50,523
C.	TOTAL OTHER DIRECT COSTS	30,376
D.	TOTAL DIRECT COSTS	113,828
E.	TOTAL INDIRECT COSTS	18,269
F.	TOTAL INDIRECT AND DIRECT COSTS	132,097
G.	FEE @ 5%	6,605
H.	TOTAL COSTS	$138,702

Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: (617) 548-1400
Telex: 951679

April 26, 1984

Dr. Ron Bretsler
Battelle Labs
397 Washington Street
Duxbury, MA 02332

Dear Ron,

I am willing to act as a consultant to Battelle on the New Bedford Harbor Project for up to 20 days for a fee of $500/day.

I will be willing to assist or advise Battelle in general modeling of the Bay and outer Harbor. Several specific tasks involved in modeling are proposed in the attached description.

Sincerely,

Bill

Dr. William D. Grant
Associate Scientist
Ocean Engineering Department

WDG/gam
enclosures

SPECIFIC PROPOSED MODELING TASKS

As a follow-up to our recent discussions on modeling strategy for the New Bedford Harbor/PCB Superfund Study I have provided here a brief summary of proposed treatment of several key modeling components. A set of reprints describing the components is enclosed to provide additional detail. The modeling components addressed here are (1) a simplified formulation for prediction of bottom stress, or actually a drag coefficient for combined wave and current flows over rough bottoms, (2) suspended sediment formulation under combined wave and current flows including treatment of the reference concentration at the bed and (3) bedload transport under combined wave and current flows.

The motivation behind the discussion of these three components follows from observations of the flow and sediment characteristics of the New Bedford Outer Harbor and Buzzards Bay. Field observations demonstrate that under strong sediment resuspension and transporting events the most energetic components in the flow field at the seabed are at the wind driven and tidal frequencies (for the currents) and at the surface wave frequencies. The bottom sediments vary significantly, but generally fall in the silty sand to sand category. The bottom is generally highly bioturbated. Under non-storm conditions the only bed relief is associated with small biologically induced mounds or furrows. During strong storms, however, in the silty-sand and sandy sediments, bedforms or specifically, wave formed ripples can occur. Thus, the storm conditions in the shallower regions of Buzzards Bay are similar to open mid and inner continental shelf conditions.

Such flow fields have been treated extensively by recent theoretical and field programs (for example, see Smith, 1977; Grant and Madsen, 1979, 1982; Grant et al., 1982; Grant and Glenn, 1983; Grant et al., 1984). The bottom stress field under such conditions is dominated by wave-current interaction with the effects of moveable bed behavior (i.e., ripples, near bed transport) playing an important role. Wave-current interaction enhances the mean stress above the wave boundary layer (i.e., the lower 5-10 cm) and results in an enhanced or apparent bottom roughness which depends on the wave conditions relative to the current and the bed conditions (i.e., ripples, etc.). Resuspension of the bottom sediment is controlled by the instantaneous stress for the combined flow, but is primarily dominated by wave induced stresses. The local mean circulation is, of course, strongly influenced by the mean boundary shear stress in such shallow, frictionally dominated systems. It is this circulation which transports the suspended sediments. In addition, the vertical distribution of the suspended sediment is controlled by turbulent mixing which also depends on the mean bottom friction and associated vertical shear.

Thus, it is clear that any model that hopes to model an area such as Buzzards Bay must treat both the steady and unsteady components of the flow as well as their interaction with the sediment bed. Since these flow components are coupled through non-linear dynamics in the form of wave-current interaction and to the bed conditions which depend on the boundary shear stress through non-linear friction, separate models for each individual process (i.e., waves, currents, etc.) cannot simply be added together. The boundary layer models which treat such combined flows are fairly involved. In addition, there are other complicating factors in modeling the area which include complicated topography in some areas and effects of advection. The situation in storms dictates that the flow will be a depth limited boundary layer with complicated dynamics resulting from interaction between the surface mixed layer and bottom boundary layer. Moreover, the ability to predict shallow water waves in such a complicated region is very limited. Thus, while it is clear that important dynamics such as wave-current interaction must be included, it is also clear that it is justifiable to include them in a simple way compatable with other simple parameterizations in the model.

(1) In parallel with these conclusions we propose to provide you with simplified versions of wave-current interaction models over moveable beds and to help you inplement these into your model. Basically, this will allow the bottom drag coefficient to be calculated from knowledge of wave height, wave period, water depth, sediment type, and the velocity at a specified reference height, say one meter above the bottom. The simplified model results will be compared with a full boundary layer model and field data to demonstrate sensitivity of the calculation to the simplifications.

The results from step one will allow the general circulation in the outer harbor and bay to be calculated including in a simple fashion the effect of waves and moveable bed conditions. In other words, the important non-linear effects are related. A field program designed to provide Lagranian velocities using drifters, flux through the mouth of the Bay and sea level response to tidal and wind forcing is proposed in a companion document.

(2) The next step is to calculate the sediment transport. The first step allowed sediment transport effects to be coupled with the boundary layer dynamics through the bottom boundary condition (i.e., bedform development, etc.). The other significant coupling between the sediment field and momentum field is through stratification associated with suspended sediment (e.g., see Grant and Glenn 1983). This buoyancy induced effect depends on the vertical sediment concentration gradient over all sediment size classes or alternatively the concentration weighted fall velocity. The condition is easily checked for using available theory and in general, in Buzzards Bay should not be significant. This is because silt has little concentration gradient and the volumes of fine sand available are generally too small. Thus, as a first pass this allows us to retain only coupling between sediment and flow at the bed.

The theoretical treatment of the suspended sediment field under a combined wave and current and solutions for the mean concentration profile as a function of sediment size class are available in Grant and Glenn (1983). The other complication is the treatment of the bed condition to calculate the reference concentrations. This can be calculated for each size class as a function of the concentration at the bed of the size class times the excess (above critical) stress. The complication in using this formulation are several.

(a) For a bed composed of a sediment mixture the bed concentration changes as a function of time due to selective resuspension of the fines.
(b) The critical stress may be largely modified by biological processes.
(c) Bed armoring (complete or partial) may occur. This means bedload

transport must be considered and availability of the fines may change. This is a particularly important consideration since we may be particularly interested in one specific size class and therefore it is critical to treat this condition realistically.

To treat this boundary condition we propose several things. First, at high wave shear stresses expected in storms, modifications of the critical stress by biological effects may not be as critical since mechanical reworking probably removes most adhesive sediment effects. We are presently looking at this problem in a Sea Grant sponsored laboratory flume study using sediment and biological organisms typical of several New Bedford areas. The critical stress values for abiotic sediment are based on uniform sediment mixtures, with flat beds (Shields curve, e.g., Madsen and Grant 1977); the conditions in the field are non-uniform bed with bedforms. These conditions in the field place uncertainty on the use of the abiotic value of Shields parameter. Moreover, the uncertainty in the constant in the reference concentration formulation is as big as the uncertainty in the critical stress. So, in conclusion it makes little sense to worry too much about this problem and instead to put error bars on the transport calculations.

A more important consideration is what the vertical profile of sediment in the bed looks like. This will be controlled primarily by biological processes since simple settling arguements would cause one to expect a layered sediment bed. The rate of reworking of the bed immediately after a storm and the depth of reworking will affect the value of the bed reference concentration. We are looking at this problem as part of our Sea Grant 1984 project. With reasonable knowledge of the vertical bed profile as a function of season, storm frequency, etc. an empirical bed concentration term can be derived and be included through a simple conservation law into the bed reference condition.

The bed armoring problem can also be treated in the same formulation. The major consideration is that bedload transport may occur. This will be considered using the bedload formulation of Madsen and Grant (1977) and modified by Grant and Glenn (1983).

In summary, the above discussion proposes treatment of the critical dynamics (wave, currents and moveable bed processes) in the New Bedford Harbor/Buzzards Bay system in a simplified fashion which still retains the major dynamical effects but is compatable with the accuracy of the other modeling components. For example, surface waves can only be approximately specified at the site; uncertainty exists in constants and critical stress values in boundary condition formulations; three dimensional mixing dynamics and upper mixed layer dynamics can be included only approximately. The advantage of the approach is that it allows the sediment transport and circulation calculations to be made independently, but still retains the critical coupling.

The intent of the project is to use the modeling along with field observations to make intellegent management decisions concerning the fate and pathways of PCBs from New Bedford Harbor. The proposed modeling simplifications are clearly compatable with this philosophy. However, the proposed additions to the circulation model remove a key set of processes from the need for empirical tuning in the model. This is a particularly important consideration for storms where high quality tuning data may be difficult to get.

References

Madsen, O.S. and W.D. Grant, 1977.
Quantitative Description of Sediment Transport by Waves, Proceedings of the Fifteenth Coastal Engineering Conference, Vol. II, 1093-1112.

Smith, J.D., 1977.
Modeling of sediment transport on continental shelves, in The Sea, 6, Wiley-Interscience, New York.

Grant, W.D. and O.S. Madsen, 1979.
Combined Wave and Current Interaction With a Rough Bottom, Journal of Geophysical Research, 84 (C4), 1797-1808.

Grant, W.D. and O.S. Madsen, 1982.
Moveable Bed Roughness in Unsteady Oscillatory Flow, Journal of Geophysical Research, 87 (C1), 469-481.

Grant, W.D., L. Boyer and L.P. Sanford, 1982.
The Effects of Bioturbation on the Initiation of Motion of Intertidal Sands, Journal of Marine Research, 40, 659-677.

Grant, W.D. and S.M. Glenn, 1983.
Continental Shelf Bottom Boundary Layer Model: Theoretical Model; Vol. I, Final Report to American Gas Association, PR-153-126, May 31, 163 pp.

Grant, W.D., A.J. Williams, 3rd and S.M. Glenn, (in press).
Bottom Stress Estimates and Their Prediction on the Northern California Continental Shelf During CODE-1: The Importance of Wave-Current Interaction, Journal of Physical Oceanography.

4. MANAGEMENT

4.1 MANAGEMENT TEAM

Dr. Jerry M. Neff will be Project Manager for this work assignment. Dr. Neff will be directly responsible to NUS and EPA and to his line manager at Battelle, Dr. A.P. Graffeo, Director of Battelle New England Marine Research Laboratory, for the quality and timely completion of the project. The members of the Project Management Team are identified in the work breakdown structure diagram (Figure 4.1.1). Dr. Hal Petersen (Battelle New England) is Task Leader for data management. Dr. Petersen will use his unique talents to manage the storage, retrieval, and manipulation of the large database which will be developed in this project. The Quality Assurance/Quality Control Officer for this project is Dr. Christine Werme (Battelle New England). She will conduct frequent QA/QC audits of the field sampling, laboratory studies and data management tasks at Battelle New England and will interact with QA/QC personnel of the subcontractors to assure that they are practicing appropriate QA/QC procedures. She will report to the Project Manager the results of these audits.

Dr. Ronald J. Breteler (Battelle New England) is the Field Program Task Leader. He will be responsible for coordination and logistics planning of the field sampling and field hydrodynamics studies. Task Leader for the laboratory analysis task, including the experimental laboratory investigations, is Dr. Paul D. Boehm. He will be responsible for review and evaluation of all analytical chemical data generated in the program. If the chemical analyses are performed at Battelle, he will be in charge of managing the actual analytical effort as well. Coordination and integration of the two modeling efforts is the responsibility of Dr. Neff. Task Leader for the physical/chemical modeling is Dr. Yasuo Onishi (Battelle Northwest). Task Leader for the food-chain modeling is Mr. John St. John (HydroQual). Dr. Neff also will be responsible for coordinating the preparation and submission of all reports.

4.2 MANAGEMENT SYSTEM AND MANAGEMENT CONTROLS

In order to provide NUS and EPA with the best possible results within time and funding constraints, the Project Manager, Dr. Neff, will use tried-and-proven Battelle management tools for managing the schedule, the quality, and the costs of the Project and its component tasks. These controls will serve to identify any potential problems at an early stage and provide immediate resolution of problems and conflicts in a manner most responsive to NUS's needs.

The complexity of managing the flow of tasks in this project, and the need to provide and demonstrate stewardship of funds provided to Battelle by NUS is recognized. Our management system will comply with EPA reporting schedules and guidelines, while at the same time providing for rigid budget and schedule monitoring. Management techniques to be used in the proposed program are those presently operative at Battelle and are used to meet contract requirements for the technical, administrative, and financial aspects of our large multidisciplinary programs. All business systems that require Government approval are currently unconditionally approved.

4.2.1 Work Breakdown Structure

The work breakdown structure for this project is shown in Figure 4.2.1. The major tasks in this work assignment are indicated. In addition, we further divide the tasks into subtasks to reflect the manner in which we intend to track both performance and cost. The number in the upper left-hand corner of each box is the subaccount number for that particular task or subtask. Project funds are opportioned to each task or subtask as indicated in the enclosed OP Form 60s. Each task or subtask account can be tracked separately at different levels, as appropriate (e.g., in management, at the 1000, 1100, or 1110 levels). Each of these tasks and subtasks has a specific Work Plan associated with it. These are contained in Section 3 of this Work Plan. Thus, costs and performance can be tracked at any level from the overall project down to individual subtasks. This provides an efficient means of early identification of any slippage in budget and performance.

4.2.2 Line of Balance

Figure 4.2.2 shows the line of balance or PERT chart for this project. Activities, responsible parties, and dates of performance of all components of the PERT are summarized in Table 4.2.1. The critical path of the project is indicated by the dark line running through the chart from left to right. As can be seen in the PERT, the analytical chemistry task is in the critical path of the overall project. Any delays in

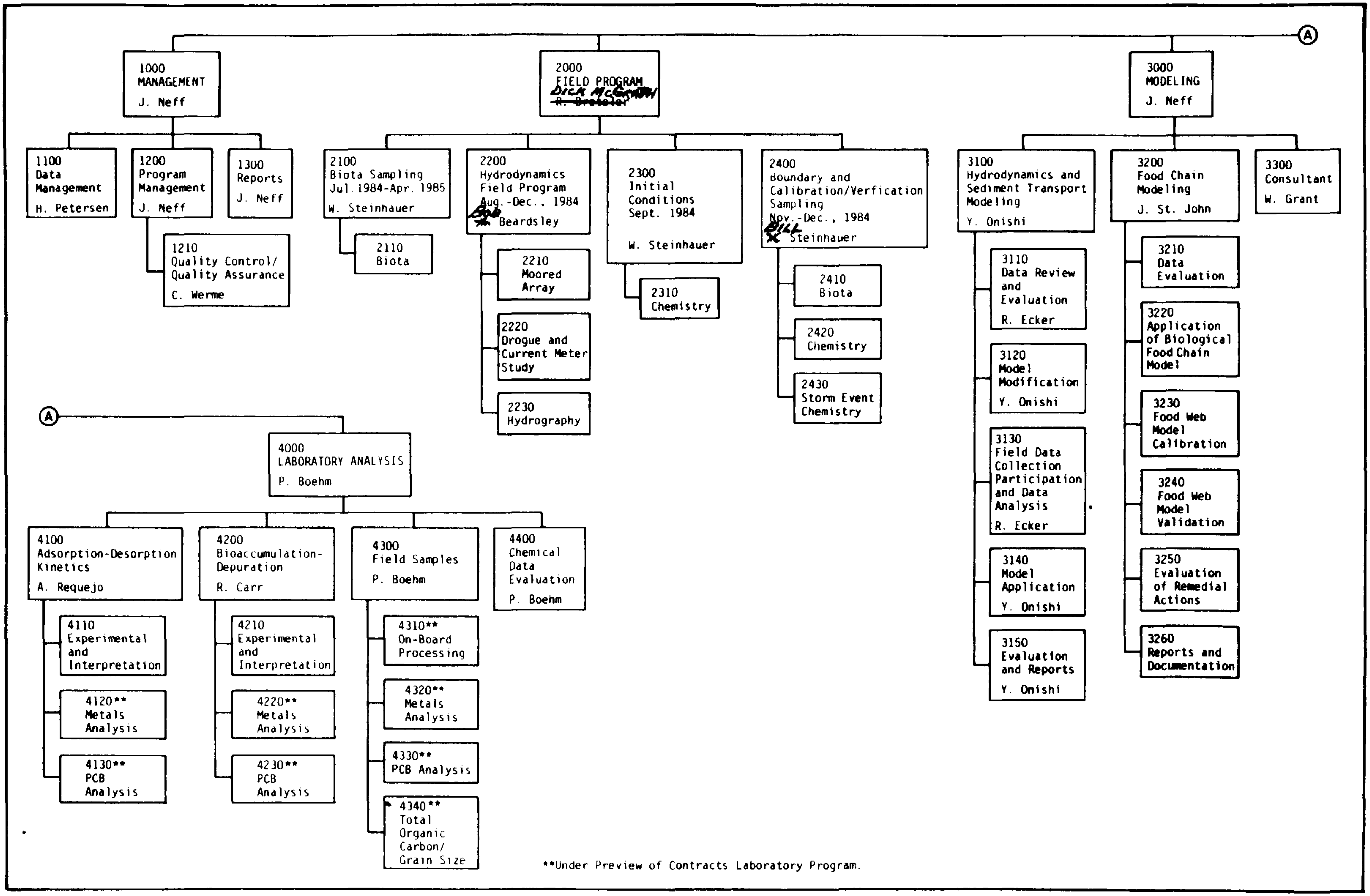


FIGURE 4.2.1. WORK BREAKDOWN STRUCTURE FOR THE NEW BEDFORD HARBOR PCB MODELING PROJECT.

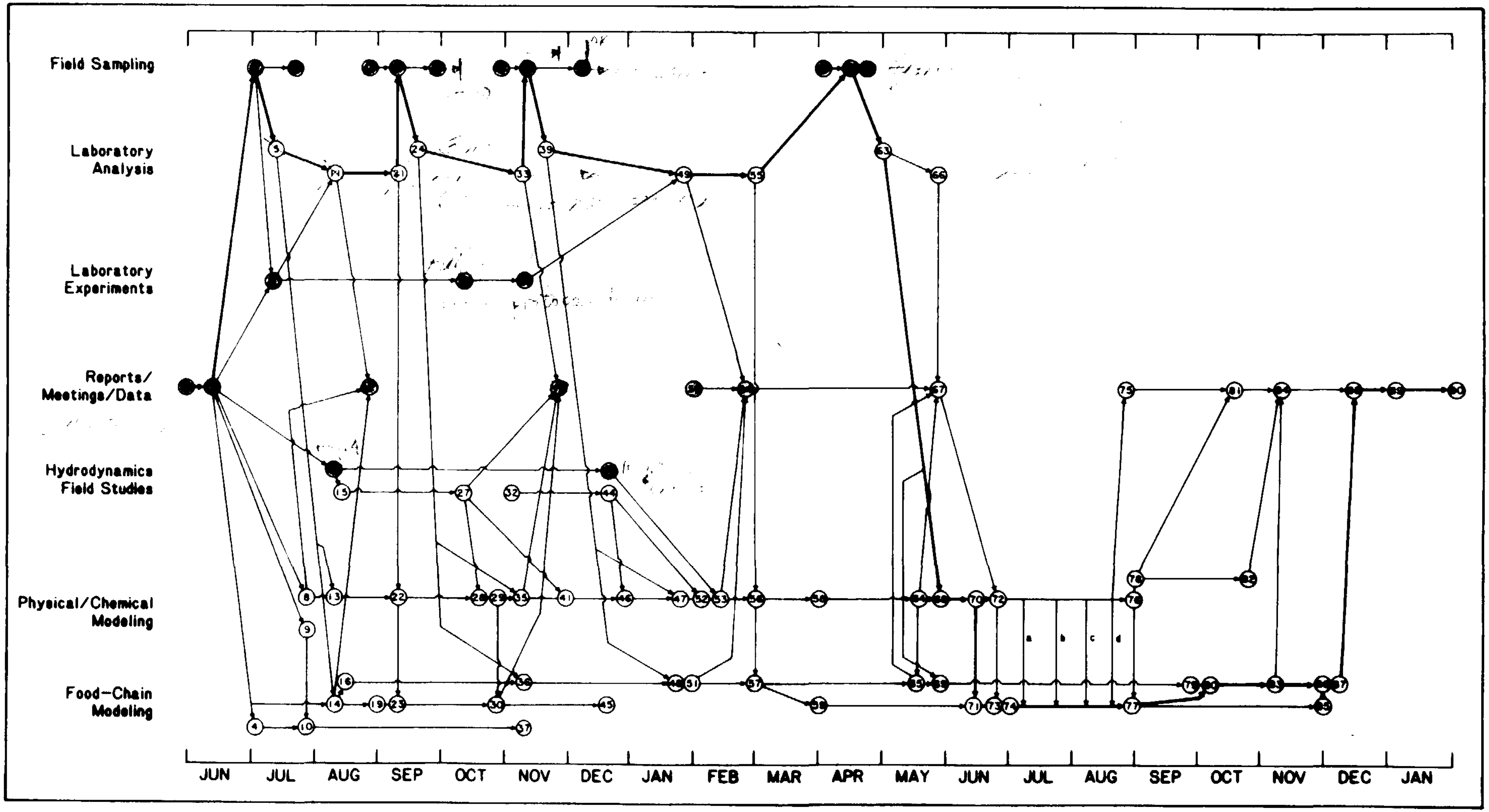


FIGURE 4.2.2. PERT CHART FOR THE NEW BEDFORD HARBOR PCB MODELING PROGRAM.

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 5

NAME OF OFFEROR: Battelle Memorial Institute

HOME OFFICE ADDRESS: 505 King Avenue, Columbus, Ohio 43201

SUPPLIES AND/OR SERVICES TO BE FURNISHED: Modeling Transport of PCB and Metals in New Haven Harbor

PROGRAM SUMMARY

DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Columbus Laboratories

TOTAL AMOUNT OF PROPOSAL: $ 1,454,400.

GOV'T SOLICITATION NO.:

DETAIL DESCRIPTION OF COST ELEMENTS

Item			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL (Itemize on Exhibit A)					
a. Materials, Supplies, and Miscellaneous			22,910		
b. SUBCONTRACTED ITEMS			813,861		
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				836,771	
2. MATERIAL OVERHEAD[3] (Rate %X$ base=)					
3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
Professional	5477	30.63	167735		
Nonprofessional	2872	10.62	30504		
TOTAL DIRECT LABOR				198,239	
4. LABOR OVERHEAD (Specify Department or Cost Center)[3]	O H RATE	X BASE =	EST COST ($)		
General Overhead	81	198239	160574		
Research Department Burden	33	198239	65419		
TOTAL LABOR OVERHEAD				225,993	
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION			2135		
b. PER DIEM OR SUBSISTENCE			2220		
TOTAL TRAVEL				4,355	
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
W. Grant - 20 days @ $500.00/day			10000		
TOTAL CONSULTANTS				10,000	
9. OTHER DIRECT COSTS (Itemize on Exhibit A)				65,102	
10. TOTAL DIRECT COST AND OVERHEAD				1,340,460	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.)					
12. ROYALTIES[4]					
13. TOTAL ESTIMATED COST				1,340,460	
14. FEE OR PROFIT				113,940	
15. TOTAL ESTIMATED COST AND FEE OR PROFIT				1,454,400	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

This proposal is submitted for use in connection with and in response to (Describe RFP, etc.)

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Robert N. Myers Contracting Officer	Robert N Myers

NAME OF FIRM	DATE OF SUBMISSION
Battelle Memorial Institute, Columbus Laboratories	May 18, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST ($)

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
Defense Contract Audit Agency 505 King Avenue Columbus, Ohio 43201	(614)424-7800/FTS 976-7800

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

N/A [ ] YES [ ] NO *(If yes, identify.)*: [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes

OPTIONAL FORM 60 (10-71)

CONTRACT PRICING PROPOSAL

(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 2 | NO. OF PAGES 5

NAME OF OFFEROR: Battelle Memorial Institute	SUPPLIES AND/OR SERVICES TO BE FURNISHED: Modeling Transport of PCB and Metals in New Haven Harbor TASK 1000 - MANAGEMENT
HOME OFFICE ADDRESS: 505 King Avenue Columbus, Ohio 43201	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Columbus Laboratories	TOTAL AMOUNT OF PROPOSAL: $ 318,419.
	GOV'T SOLICITATION NO.

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL (Itemize on Exhibit A)					
a. Materials, Supplies, and Miscellaneous			4000		
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				4,000	
2. MATERIAL OVERHEAD[3] (Rate %X$ base=)					
3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
Professional	2889	35.81	103449		
Nonprofessional	1363	9.82	13386		
TOTAL DIRECT LABOR				116,835	
4. LABOR OVERHEAD (Specify Department or Cost Center)[3]	O H RATE	X BASE =	EST COST ($)		
General Overhead	81	116835	94636		
Research Department Burden	33	116835	38556		
TOTAL LABOR OVERHEAD				133,192	
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
W. Grant - 20 days @ $500.00/day			10000		
TOTAL CONSULTANTS				10,000	
9. OTHER DIRECT COSTS (Itemize on Exhibit A)				29,447	
10. TOTAL DIRECT COST AND OVERHEAD				293,474	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.)					
12. ROYALTIES[4]					
13. TOTAL ESTIMATED COST				293,474	
14. FEE OR PROFIT				24,945	
15. TOTAL ESTIMATED COST AND FEE OR PROFIT				318,419	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

This proposal is submitted for use in connection with and in response to (Describe RFP, etc.)

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Robert N. Myers Contracting Officer	Robert N Myers

NAME OF FIRM	DATE OF SUBMISSION
Battelle Memorial Institute, Columbus Laboratories	May 18, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST ($)

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
Defense Contract Audit Agency 505 King Avenue Columbus, Ohio 43201	(614)424-7800/FTS 976-7800

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

N/A [ ] YES [ ] NO *(If yes, identify.)*: [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM 60 (10-71)

ESTIMATED COST DETAIL   TASK 1000 - MANAGEMENT

DIRECT MATERIAL

a. Materials, Supplies, and Miscellaneous

Item Description	Quantity	Unit Price	Cost
Miscellaneous Materials			4,000.
		Total $	4,000.

b. Subcontracted Items

Item Description	Vendor	Cost
	Total $	

Total Direct Material $ 4,000.

TRAVEL

Destination	No. Trips	No. Men	No. Days per Trip	Total No. Man-Days	Total Subsistence	Total Round Trip Fare	Ground Transport	Total Cost

Total Transportation ______ Total Subsistence ______ Total Travel $ ______

C15 (4-82) Rev.

OTHER DIRECT COSTS

a. Use of Equipment

Item Description	Rate	No. Units	Cost
General Support Facilities - Dept. 500	11%	113518.	12,487.
VAX Computer	13/hr.	1154	15,000.
Office Copier	.07	28000	1,960.
		Total	$ 29,447.

b. Service Center/Special Facility Burdens

Area	Rate	Basis	Cost
		Total	$

c. Duplicating and Photographic Services

Item Description	Cost
Total	$

d. Nuclear Services $

e. Hot Laboratory Decontamination $

f. Hazardous Materials Laboratory Decontamination $

g. Cost of Facilities Capital $

Total Other Direct Costs $ 29,447.

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 3 | NO. OF PAGES 5

NAME OF OFFEROR: Battelle Memorial Institute

HOME OFFICE ADDRESS: 505 King Avenue, Columbus, Ohio 43201

SUPPLIES AND/OR SERVICES TO BE FURNISHED: Modeling Transport of PCB and Metals in New Haven Harbor

TASK 2000 - FIELD PROGRAM

DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Columbus Laboratories

TOTAL AMOUNT OF PROPOSAL: $ 281,628.

GOV'T SOLICITATION NO.:

DETAIL DESCRIPTION OF COST ELEMENTS

1. DIRECT MATERIAL (Itemize on Exhibit A)			EST COST ($)	TOTAL EST COST	REFERENCE
a. Materials, Supplies, and Miscellaneous			10,660		
b. SUBCONTRACTED ITEMS			138,702		
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				149,362	
2. MATERIAL OVERHEAD (Rate %X$ base=)					
3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
Professional	1477	20.98	30985		
Nonprofessional	688	9.00	6192		
TOTAL DIRECT LABOR				37,177	
4. LABOR OVERHEAD (Specify Department or Cost Center)	O H RATE	X BASE =	EST COST ($)		
General Overhead	81	37177	30113		
Research Department Burden	33	37177	12268		
TOTAL LABOR OVERHEAD				42,381	
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION			2135		
b. PER DIEM OR SUBSISTENCE			2220		
TOTAL TRAVEL				4,355	
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
TOTAL CONSULTANTS					
9. OTHER DIRECT COSTS (Itemize on Exhibit A)				26,290	
10. TOTAL DIRECT COST AND OVERHEAD				259,565	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.)					
12. ROYALTIES					
13. TOTAL ESTIMATED COST				259,565	
14. FEE OR PROFIT				22,063	
15. TOTAL ESTIMATED COST AND FEE OR PROFIT				281,628	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Robert N. Myers Contracting Officer	Robert N Myers

NAME OF FIRM	DATE OF SUBMISSION
Battelle Memorial Institute, Columbus Laboratories	May 18, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST ($)

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
Defense Contract Audit Agency 505 King Avenue Columbus, Ohio 43201	(614)424-7800/FTS 976-7800

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

N/A [ ] YES [ ] NO *(If yes, identify.)*: [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes

OPTIONAL FORM 60 (10-71)

ESTIMATED COST DETAIL TASK 2000 - FIELD PROGRAM

DIRECT MATERIAL

a. Materials, Supplies, and Miscellaneous

Item Description	Quantity	Unit Price	Cost
Mooring Fees			660.
Field Supplies			6,000.
Lobster Fisherman			4,000.

Total $ 10,660.

b. Subcontracted Items

Item Description	Vendor	Cost
Hydrodynamics	W.H.O.I.	138,702.

Total $ 138,702.

Total Direct Material $ 149,362.

TRAVEL

Destination	No. Trips	No. Men	No. Days per Trip	Total No. Man-Days	Total Subsistence	Total Round Trip Fare	Ground Transport	Total Cost
New Bedford, MA	37	4	1	148	2,220.		2,135.	4,355.

Total Transportation 2,135. Total Subsistence 2,220. Total Travel $ 4,355.

OTHER DIRECT COSTS

a. Use of Equipment

Item Description	Rate	No. Units	Cost
General Support Fac~~ilities~~ - Dept. 500	11%	37177	4,090.
R/V Mya	600/day	37	22,200.

Total $ 26,290.

b. Service Center/Special Facility Burdens

Area	Rate	Basis	Cost

Total $

c. Duplicating and Photographic Services

Item Description	Cost

Total $

d. Nuclear Services $

e. Hot Laboratory Decontamination $

f. Hazardous Materials Laboratory Decontamination $

g. Cost of Facilities Capital $

Total Other Direct Costs $ 26,290.

TABLE 4.2.1. DESCRIPTION OF KEY ACTIVITIES IN THE NEW BEDFORD HARBOR MODELING PROGRAM AS SHOWN GRAPHICALLY IN THE ACCOMPANYING PERT CHART (FIGURE 4.3.1).

Activity	Description	Responsible Organization[1]	Dates
1-2	Project start-up	All	6/1-6/11/84
2	Project start-up meeting	All	6/11
2-3	Prepare for first field sampling trip	BNE	6/11-7/2
2-4	Begin Review/Evaluation of existing data for food-chain model	HQ	6/13-7/2
2-8	Make initial modification of physical/chemical model	BNW	6/13-7/27
2-9	Make initial review of physical/chemical models	BNW	6/13-7/27
2-19	Undertake literature review of generic data for food-chain model	HQ	6/13-8/31
3-6	Deliver site sediment and water samples for laboratory experiments	BNE	7/2-7/10
3-7	Perform First Sampling trip (biota)	BNE	7/2-7/20
3-11*	Analyze samples from First Sampling Trip	CLP	7/5-8/10
4-10	Continue Review/Evaluation of existing data for food-chain model	HQ	7/2-7/27
5-13	Deliver analytical results for First Sampling to BNW	BNE	7/10-8/10
5-14	Deliver analytical results for First Sampling to HQ	BNE	7/10-8/10
6-21*	Begin analysis of samples from laboratory experiments	CLP	8/11-9/10
6-24	Perform adsorption/desorption lab experiments	BNE	7/9-9/12
6-34	Perform bioaccumulation lab experiments	BNE	7/9-10/9
8-17	Provide input for First Quarterly Report/Meeting	BNW	7/27-8/27
8-29	Review/apply existing data for physical/chemical model	BNW	7/27-9/26
9-10	Define physical/chemical input requirements for food-chain model	BNW, HQ	7/27
10-37	Apply food-chain model (biological aspects)	HQ	7/2-10/9
11-17	Provide input for First Quarterly Report/Meeting	BNE	8/10-8/27
12-43	Perform moored array study	W.H.O.I.	8/14-12/21
14-17	Provide input for First Quarterly Report/Meeting	HQ	8/10-8/27
14-23	Evaluate preliminary field data for food-chain model	W.H.O.I.	8/14-12/21
15-27	Perform First Drogue/Current Meter Study	W.H.O.I.	8/14-10/12
16-51	Perform preliminary calibration of food-chain model	HQ	8/15-1/31/85
17	First Quarterly Report/Meeting	All	8/27
18-20	Prepare for Second Sampling Trip	BNE	9/10-9/28
20-25	Perform Second Field Sampling Trip (initial conditions)	BNE	9/10-9/28
20-33*	Analyze samples from Second Sampling Trip	CLP	9/12-11/9
21-22	Deliver preliminary results of lab experiments to BNW	BNE	9/10
21-23	Deliver preliminary results of lab experiments to HQ	BNE	9/10
23-45	Evaluate results of lab experiments for models	HQ	9/10-12/20
24-35	Deliver results of analyses of samples from Second Sampling to BNW	BNE	9/17-11/9

TABLE 4.2.1. (Continued)

Activity	Description	Responsible Organization[1]	Dates
24-36	Deliver results of analyses of samples from Second Sampling to HQ	BNE	9/17-11/9
27-28	Deliver preliminary results of First Drogue Study	W.H.O.I.	10/12-10/19
27-40	Provide input for Second Quarterly Report/Meeting	W.H.O.I.	10/12-11/26
27-41	Deliver Final Results of First Drogue Study to BNW	W.H.O.I.	11/30
29-30	Coordinate modification of physical/chemical model	BNW,HQ	10/26
30-40	Provide input for Second Quarterly Report/Meeting	HQ	10/26
31-38	Prepare for Third Sampling Trip	BNE	11/1-11/12
32-44	Perform Second Drogue/Current Meter Study	W.H.O.I.	11/5-12/21
33-40	Provide input for Second Quarterly Report/Meeting	BNE	11/10-11/26
34-49	Deliver final samples from lab experiments for chemical analyses	BNE	11/10
35-40	Provide input for Second Quarterly Report/Meeting	BNW	11/10-11/26
35-41	Evaluate results of Second Sampling for Input to physical/chemical model	BNW	11/10-12/1
38-42	Perform Third Sampling Trip (boundary-calibration-biota-storm event)	BNE	11/12-12/7
38-49*	Analyze samples from Third Sampling Trip	CLP	11/14-1/25/85
39-47	Deliver results of analyses of samples from Third Sampling to BNW	BNE	11/19-1/25
39-48	Deliver results of analyses of samples from Third Sampling to HQ	BNE	11/19-1/25
40	Second Quarterly Report/Meeting	All	11/26
41-52	Continue calibration of physical/chemical model	BNW	12/1-2/5/85
43-53	Prepare and deliver Final Report on Moored Array Study	W.H.O.I.	12/21-2/22
44-46	Deliver preliminary results from Second Drogue Study	W.H.O.I.	12/21-12/28
44-53	Prepare and deliver Final Report on Drogue Studies	W.H.O.I.	12/21-2/22
49-54	Provide input to Third Quarterly Report/Meeting	BNE	1/15-2/26
49-55*	Complete analyses of samples from lab experiments	CLP	1/25-3/1
50-67	Define remedial actions	All	2/4-5/27
51-54	Provide input to Third Quarterly Report/Meeting	HQ	2/1-2/26
51-79	Perform detailed calibration of food-chain model	HQ	2/1-9/27
53-54	Provide input to Third Quarterly Report/Meeting	BNW	2/23-2/26
54	Third Quarterly Report/Meeting	All	2/26
55-56	Deliver final results of analyses and interpretation of lab experiments to BNW	BNE	3/1
55-57	Deliver final results of analyses and interpretation of lab experiments to HQ	BNE	3/1
56-58	Assess physical/chemical model	BNW	3/1-3/29
58-70	Run physical/chemical model for base conditions	BNW	4/1-6/15

TABLE 4.2.1. (Continued)

Activity	Description	Responsible Organization[1]	Dates
59-74	Evaluate new laboratory and field data	HQ	4/1-6/28
60-61	Prepare for Fourth Sampling Trip	BNE	4/7-4/15
61-62	Perform Fourth Sampling Trip	BNE	4/15-4/19
61-66*	Analyze samples from Fourth Sampling Trip	CLP	4/17-5/27
63-68	Deliver results of analyses of samples from Fourth Sampling to BNW	BNE	4/22-5/27
63-69	Deliver results of analyses of samples from Fourth Sampling to HQ	BNE	4/22-5/27
64-65	Coordinated assessment of physical/chemical model	BNW, HQ	5/17
64-67	Provide input for Fourth Quarterly Report/Meeting	BNW	5/17-5/27
65-67	Provide input for Fourth Quarterly Report/Meeting	HQ	5/17-5/27
66-67	Provide input for Fourth Quarterly Report/Meeting	BNE	5/27
67	Fourth Quarterly Report/Meeting	All	5/27
67-72	Provide input of remedial action scenarios to physical/chemical model	BNE	5/27-6/24
67-73	Provide input of remedial action scenarios to food-chain model	BNE	5/27-6/24
70-71	Deliver base physical/chemical conditions for food-chain model to HQ	BNW	6/15
72a,b,c,d-74a,b,c,d	Deliver physical/chemical inputs for remedial actions to food-chain model	BNW	7/7-8/19
72-76	Run physical/chemical model for remedial action scenarios	BNW	6/26-8/30
74-85	Run food-chain model for remedial action scenarios	HQ	7/1-11/29
72d-75	Provide input to Fifth Quarterly Report/Meeting	BNW	8/19-8/26
74d-75	Provide input to Fifth Quarterly Report/Meeting	HQ	8/19-8/26
75	Fifth Quarterly Report/Meeting	All	8/26
75-89	Prepare Draft Integrated Final Report	BNE	8/26-12/4
76-77	Deliver final physical/chemical data for food-chain model to HQ	BNW	8/30
78-81	Deliver preliminary results from physical/chemical modeling to BNE	BNW	9/2-10/18
78-82	Prepare Draft Final Report on physical/chemical modeling	BNW	9/2-10/25
80-87	Prepare Draft Final Report on Food-Chain Modeling	HQ	10/7-12/6
82-84	Deliver Draft Final Report for physical/chemical modeling to BNE	BNW	10/25-11/8
83-84	Deliver preliminary food-chain modeling results to BNE	HQ	11/6-11/8
85-86	Incorporate final results of food-chain modeling into Final Report	HQ	11/29
87-88	Deliver Draft Final Report for food-chain modeling to BNE	HQ	12/6-12/9

TABLE 4.2.1. (Continued)

Activity	Description	Responsible Organization[1]	Dates
88-89	Continue preparation of Integrated Draft Final Report	BNE	12/9-1/3/86
89	Deliver Draft Final Report to NUS	BNE	1/3
89-90	Review and revise Draft Final Report	All	1/3-1/31
90	Deliver Final Report to NUS	BNE	1/31/86

1, BNE, Battelle New England Marine Research Laboratory;
BNW, Battelle Pacific Northwest Laboratories;
CLP, Contract Laboratory Program, EPA;
HQ, HydroQual, Inc.;
W.H.O.I., Woods Hole Oceanographic Institution.

*Chemical analyses not currently a part of this work plan; shown here to document relationship of analytical chemistry component to the overall program.

events along the critical path will have serious impacts on the schedule of the overall program. Using the PERT chart and the documentation that accompanies it, it is possible to see at a glance what activities should be taking place on any date during the program. Therefore, the PERT chart is a very valuable tool for managing the project schedule.

4.2.3 Manpower Loading

At the outset of this project, the Project Management Team will develop manpower loading charts to document specific manpower requirements and work schedules for each task. During the project, actual hours charged to each task will be compared to the estimated manpower loading charts to track labor dollars expended.

4.2.4 Resolution of Conflicts and Problems

Battelle recognizes that a multidisciplinary program such as the one proposed here can encounter a variety of scheduling problems and/or conflicts centered around the various data acquisition and data management tasks comprising the concurrent work tasks being executed. These problems could involve manpower scheduling, budgetary elements and data quality.

The centralized program management structure is oriented towards two activities that will effectively resolve any such problems:

1. Early problem/conflict recognition through use of effective management controls and tools.

2. Clear, timely, effective lines of communication and authority.

The core management group represents a closely working interactive group of scientists, supported by a responsive contracting officer and administrative group on-site at Battelle New England. This group will have the clear knowledge of the scope of the program's varied tasks.

4.2.5 Cost Control

Dr. Neff will have responsibility for controlling costs and will be strongly assisted by the Task Managers. He will approve any commitment of funds and closely monitor **Monthly Financial Reports.**

In a large interdisciplinary project, cost control is a critical element which must be closely monitored by the project management. Work tasks can be broken down into individual costed subelements, when desired, to maintain close control over critical tasks or subtasks. Battelle's cost control system is responsive to the project requirements and will provide quick response and accurate cost accounting to the Project Management Team and to NUS. The cost control activity will be supported by Mr. Robert Myers, the Contracting Officer, and Ms. Roberta Cook of his staff, who are responsible to Dr. Graffeo, Director of Battelle New England. They will analyze the cost reports and report to Dr. Neff variances between budgets and actual expenditures.

At the point of initiation of this project, Dr. Neff will give each Task Leader a budget for his areas of responsibility. Routinely furnished to Dr. Neff, as well as the individual principally responsible for work elements, will be Monthly Cost Reports showing categories of costs for each work element of each work assignment (e.g., Figure 4.2.3) as specified in the work breakdown structure. A detailed breakdown of the individual charges in each of these categories will be obtained for each account number. A record of the staff time charged to each account by individual will be supplied monthly.

Furthermore, for the entire Work Assignment and each of its elements, a summary of costs will be prepared (Figure 4.2.4). This summary will be reviewed by the Program Manager and the EPA Project Officer in tabular (Figure 4.2.4) and graphical (Figure 4.2.5) forms. Such presentations alert Dr. Neff to any developing problem.

Changes in cost account budgets which result from project redirection will be authorized through Subaccount Revision Forms which can close subaccounts, open new subaccounts, or transfer funds from one subaccount to another. These forms will show the funding changes and also show additions to the scope of work and changes in start and completion dates of the tasks covered by the various subaccounts. They will be signed by Dr. Neff and the affected Task Leaders to signify understanding and agreement on the cost, schedule, and scope of work changes.

This cost/schedule planning and control system provides for continuous tracking and evaluation of cost-schedule status and performance against agreed-upon

Battelle

GRAPHIC PERFORMANCE REPORT

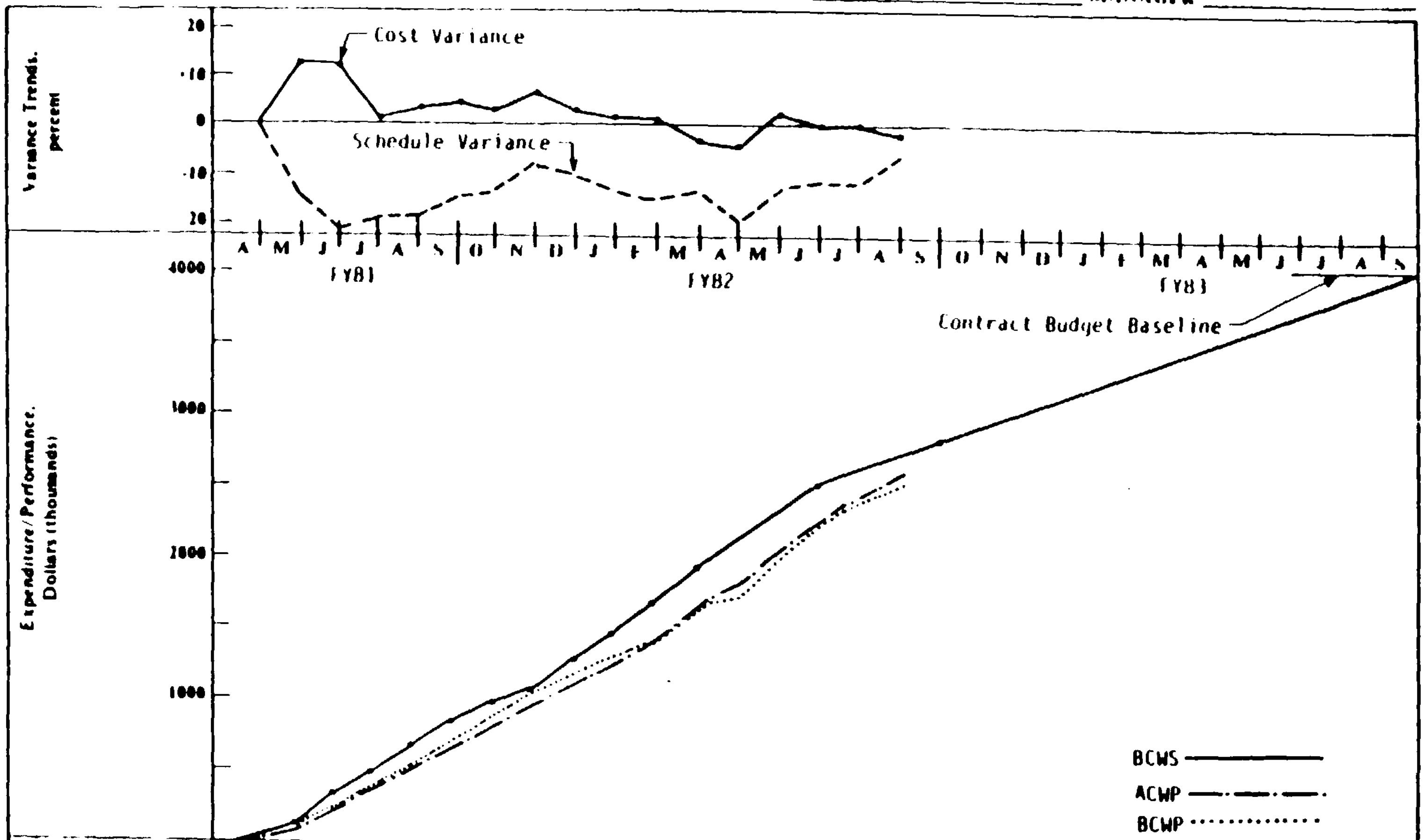
PROJECT XXXX

CWBS NO. XXXX

TITLE Phase II Option 1 Manufacturing Technology

DATE September 21, 1982

MANAGER H. C. Abrams



CAUSE

Schedule has been delayed by slippage on Task C Establish specification and difficulty arranging project review meeting which was delayed 3 weeks

IMPACT

Schedule has slipped 6 weeks, but will not affect detail design because of built in slack time

CORRECTIVE ACTION — DATE SV GOES TO ZERO

Task 3 has been completed and additional designers are planned to gain 2 weeks. Schedule Variance (SV) is planned to go to zero at end of December

PMS Form No. 7 (1/83)

FIGURE 4.2.3. SAMPLE MONTHLY COST SUMMARY SHEET FOR EACH WORK ITEM.

STATUS REPORT

FOR MONTH OF NOV 81

SUBTASK ID: 4200 TITLE: ESTABLISH PRELIMINARY DESIGN DATE: 22-DEC-81

EVENT ID	DESCRIPTION	SCHEDULE DATE	TOTAL BUDGET	BCWS NOV 81	BCWP	ACWP	ETC	ECAC	SCHEDULE VARIANCE	COST VARIANCE	BUDGET VARIANCE
4201	ESTABLISH IWAG PRELIMINARY DESIGNS	10/31/81	86390	86390	86390	124421	0	124421	0	-38031	-38031
4202	ESTABLISH IWRC PRELIMINARY DESIGN	06/30/82	183728	81021	80713	62056	103015	165071	-308	18657	18657
4203	ESTABLISH EMF PRELIMINARY DESIGN	09/30/82	180000	0	0	0	180000	180000	0	0	0
4204	SUBTASK PLANNING AND CONTROL	09/30/82	32399	10830	10830	6631	21569	28200	0	4199	4199
4211	WELDING	10/31/81	27026	27026	27026	29954	0	29954	0	-2928	-2928
4212	IWRC PREL DESIGN-CONTROLS	07/01/82	145240	16870	16870	9618	128370	137988	0	7252	7252
4221	GRINDING	10/31/81	14688	14688	14688	16829	0	16829	0	-2141	-2141
4222	EST. IWRC PRELIM. DESIGN-MATL HANDLI	06/25/82	26933	2838	2483	2755	24450	27205	-355	-272	-272
4231	INSPECTION	10/31/81	35630	35630	35630	28403	0	28403	0	7227	7227
4232	ESTABLISH IWRC PRELIM. DESIGN-INSPEC	03/05/83	17820	4320	2700	3896	15120	19016	-1620	-1196	-1196
4241	MATERIAL HANDLING	10/31/81	14837	14837	14837	10939	0	10939	0	3898	3898
4251	SOFTWARE	10/31/81	18675	18675	18675	34552	0	34552	0	-15877	-15877
4261	MODELING & SIMULATION	10/31/81	10020	10020	10020	47254	0	47254	0	-37234	-37234
4271	SUBCONTRACTORS		0	0	0	0	0	0	0	0	0
	TOTAL	03/05/83	793386	323145	320862	377308	472524	849832	-2283	-56446	-56446

FIGURE 4.2.4. PMS STATUS REPORT EXAMPLE.

O/H RATE 8100 — C O S T   S H E E T   O — SEC 501

START 1/21/82   EXPIRE 12/31/83 — PROJECT OR ACCT CI
PROJECT TITLE - INT BU LAND MGMT — C4 — G 7970 — CON
SPONSOR NAME - INT BU LAND MGMT
DISTRIBUTION - NEFF JM

	AUG 83	SEP 83	OCT 83	CUM COSTS
34 APPROPRIATION	2955446.00	2955446.00	2955446.00	0.00
35 DIRECT LABOR $ - MEMO	35963.58	20827.42	33680.56	781567.54
36 STAFF TIME	35963.58	20827.42	33680.56	781551.37
38 REPORT + PHOTO SERVICES	0.00	0.00	0.00	132.16
41 SPECIAL FACILITIES	.56	698.46	503.02	7081.73
42 GEN SUPPORT FACILITIES	5753.43	3332.34	5388.84	125000.76
44 PURCHASES	424.00	840.24	4678.09	109115.96
45 SUBCONTRACT AND CONSULT	10082.47	0.00	165501.89	468050.65
46 STORES WITHDRAWALS	0.00	0.00	.68	.68
48 MISCELLANEOUS	0.00	27.20	24.80	757.41
52 RESEARCH DEPT BURDEN	10789.10	6248.2[illegible]	10104.24	234470.88
53 OVERHEAD AT 81. 0 %	29130.51	16870.[illegible]	27281.25	633069.79
54 CST OF FACILITY CAPITAL	5133.59	2973.00	4807.70	127635.89
55 TRAVEL	167.66	214.71	28.80	3956.44
58 TOTAL COSTS	97444.90	52031.85	251999.87	2490823.72
59 WRITEOFF/WRITEON	0.00	0.00	0.00	-80000.00
60 NET COSTS FOR THE MONTH	97444.90	52031.85	251999.87	2410823.72
61 CUMULATIVE COSTS	2106792.00	2158823.85	2410823.72	0.00
63 UNEXPENDED BALANCE	848654.00	796622.15	544622.28	0.00
64 OPEN PURCH COMMIT			107941.07	
UNCOMMITTED BALANCE			436681.21	
65 FEE APPROPRIATION				210040.00
66 FEE COSTED (7.11 %)			17917.19	177097.57
67 UNCOSTED FEE				32942.43

FIGURE 4.2.5. GRAPHIC PERFORMANCE REPORT EXAMPLE.

objectives. The system also provides for flexibility and responsiveness to work assignment redirection as the project progresses.

4.3 FIELD SAMPLING QC

A quality assurance program for sampling equipment and field sampling procedures is necessary to insure data of the highest quality. Particular attention must be paid to navigational and positioning data and to the constant threat of sample contamination, either ship-specific sources (e.g., hydraulic fluids, solvents) or from cross-contamination of samples. The latter source of contamination is particularly important in the New Bedford Harbor project, in that areas of extremely high contamination are in close proximity to relatively pristine regions which will serve as background controls. Fortunately, the Battelle field party has considerable experience in the collection of environmental samples for trace metal and PCB contaminants and is well-versed in the precautions required for the successful collection of such samples.

4.3.1 Field Sampling Protocol

The first step towards assurance that samples collected as part of this study will reflect environmental levels and not artifacts of collection is the establishment of a rigid protocol of sample collection and shipboard processing. This section of the project plan contains the preliminary information which must be formalized before the first survey. The sampling protocol will define and justify equipment types and manufactureers, define shipboard conduct and precautions, as well as define strict navigation, positioning, sampling, an sample processing methods. In addition, procedures for the recording, processing, and reporting of data and procedures for the review of data will be formalized. This protocol will be adhered to for all survey operations.

4.3.2 Field Log Book

All information pertinent to a field survey and/or sampling will be recorded in a log book. This must be a bound book with consecutively numbered pages. Entries in the log book will include at least the following:

- Purpose of sampling (e.g., surveillance, contract number)
- Location of sampling point (e.g., LORAN C, navigation chart)
- Name and address of field contact
- Type of sample (e.g., sediment, water sample for PCB, wastewater)
- Number and volume of sample taken
- Description of sampling point and sampling methodology.
- Date and time of collection
- Collector's sample identification number(s)
- Field observations (e.g., sea state, tidal flow, weather conditions)

Sampling situations vary widely. No general rule can be given as to the extent of information that must be entered in the log book. A good rule, however, is to record sufficient information so that someone can reconstruct the sampling without reliance on the collector's memory.

The lab book must be protected and kept in a safe place.

4.3.3 Chain-of-Custody Record

To establish the documentation necessary to trace sample possession from the time of collection, a chain-of-custody record must be filled out and accompany every sample. This record becomes especially important when the sample is to be introduced as evidence in a court litigation. An example of a chain-of-custody record is illustrated in Figure 4.3.1. The record must contain the following minimum information:

- Collector's sample number
- Signature of collector
- Date and time of collection
- Place and address of collection
- Waste type

- Signatures of persons involved in the chain of possession
- Inclusive dates of possession.

4.3.4 Field Sampling Verification - Shipboard Contaminants

In order to assess the validity of field data, approximately five percent of the overall field program will be field quality controlled. A portion of this QC program will be the collection and analysis of a suite of samples of possible shipboard contaminants that may be used to document sources of field sample contamination (Table 4.3.1). Two sets of these samples (copper and PCB) will be collected during each sampling period to provide this information.

4.3.4.1. Shipboard Contaminants. Samples will be collected to document shipboard contamination during each of the three survey periods (Table 4.3.2).

4.3.4.2. Field Sampling Verification - Duplicate Samples. At selected stations on a random timeframe, duplicate samples from two sets of field equipment will be collected (e.g., water collected with submersible pump, duplicate collected with teflon-lined Go-Flo or stainless sampler). This provides a check on sampling equipment and technique for precision.

4.3.4.3. Field Sampling Verification - Split Samples. A representative subsample from the collected sample will be removed and analyzed for the pollutants of interest. The samples may be reanalyzed by the same laboratory or analyzed by different laboratories for a check on analytical/sampling variability.

4.3.4.4. Field Sampling Verification - Spiked Samples. Known amounts of copper or PCB will be added to selected samples or blanks at concentrations at which the accuracy of the test method is satisfactory. This method provides a proficiency check for accuracy of the analytical procedures.

TABLE 4.3.1. SHIPBOARD CONTAMINANTS

The following samples will be collected to document shipboard contamination during each of the three survey periods.

Trace Metals

1. Two atmospheric fallout samples collected by securing open Teflon jars on deck for 12-24 hours during tidal series studies. The duration of exposure must be recorded along with any pertinent meteorlogical information.

2. Four suspended particulate blanks (handling procedure, including filter rinse)

3. One sample of ship's fuel oil (250 ml)

4. One sample of ship's hydraulic fluid (250 ml)

5. Two atmospheric fallout samples collected by securing Teflon jars in laminar flow hood for 12-24 hours during tidal series studies. The duration of exposure must be recorded.

6. Four random samples of Milli-Q water (250 ml).

7. Four pore water blanks consisting of water rinse of squeezer apparatus and receiving syringe (250 ml).

Polychlorinated Biphenyls

1. Two atmospheric fallout samples (as above)

2. Four suspended particulate blanks (handling procedure)

3. One sample of ship's fuel oil (250 ml)

4. One sample of ship's hydraulic fluid (250 ml) or solvent rinse of winch cable

5. Bilge water (1 liter)

5. TIME AND COSTS

The proposed duration of the project described in this Work Plan is twenty (20) months, starting on or approximately June 1, 1984, with submission of a Draft Final Report on or before January 3, 1986 and a Final Report on or before January 3, 1986.

The total estimated cost, including fixed fee, for completion of this work is $1,454,000. A summary of these costs, by task, subtask and subaccount number is contained in Table 5.1. The costs are documented in Optional Form 60s for the total project and for each major task and for subcontractor's tasks and subtasks. These forms are attached.

Not included in this budget is the cost of on-board and immediate processing of chemistry samples, which has an estimated cost of $90,810. The analytical chemistry component of the project also has not been costed. We estimate that Battelle New England Marine Research Laboratory could perform these chemical analyses (four PCB pseudocomponents by capillary GC, plus copper by atomic absorption) for $150-$300 per sample, depending on sample type, or a total cost of approximately $375,000 for 1,875 samples. Total organic carbon/grain-size analyses would cost about $35 per sample.

In recognition of the sponsor's budget constraints for funding the New Bedford Harbor modeling project, Battelle and its subcontractors are proposing to NUS in this Work Plan a work scope that is slightly reduced from that originally called for in the RAMP Plan. We are proposing here to model four PCB pseudocomponents and one metal (copper) instead of PCBs and three metals as originally called for. Copper is the most abundant metal contaminant at the site and most of the other major metal contaminants at the site have a distribution similar to that of copper. If NUS and EPA feel that it is necessary to model three metals, this can be accomplished in the present project for an additional sum of approximately $150,000.

TABLE 5.1 COST BREAKDOWN (INCLUDING FEE) BY TASK AND SUBTASK

Task	Subtask	Account No.		Budget
MANAGEMENT		**1000**		
	Data Management	1100		76,708
	Program Management	**1200**		**171,589**
	Quality Control	1210		13,744
	Reports	1300		56,378
			Subtotal	**318,419**
FIELD PROGRAM		**2000**		
	Biota Sampling	2100		23,146
	Hydrodynamics (W.H.O.I.)	2200		150,492
	Initial Conditions	2300		39,033
	Boundary/Calibration	2400		68,957
			Subtotal	**281,628**
MODELING		**3000**		
	Physical/Chemical (BNW)	**3100**		
	Data Review	3110		32,053
	Model Modification	3120		70,291
	Collections/Analysis	3130		61,653
	Model Application	3140		181,192
	Evaluation/Reports	3150		47,714
	Food Chain (HQ)	**3200**		
	Data Evaluation	3210		17,348
	Bio-Food Chain Appl.	3220		27,045
	Model Calibration	3230		34,819
	Model Validation	3240		149,383
	Eval. Remedial Actions	3250		50,995
	Reports/Documentation	3260		60,055
			Subtotal	**732,548**
LABORATORY ANALYSIS		**4000**		
	Adsorption/Desorption	**4100**		
	Experimental	4100		37,332
	Analysis	4120		*
	Bioaccumulation	**4200**		
	Experimental	4210		32,571
	Analysis	4220		*
	Field Samples	**4300**		
	On-Board Processing	4310		**
	Lab. Anal., Metals	4320		*
	Lab. Anal. PCBs	4330		*
	TOC/Grain Size	4340		*
	Chemistry Data Evaluation	**4400**		**51,902**
			Subtotal	**121,805**
			Total for Project	**$1,454,400**

*Under perview of Contract Laboratory Program, not costed here.
**On-board processing of chemistry samples estimated at $90,810, and not included in total budget.

CONTRACT PRICING PROPOSAL (RESEARCH AND DEVELOPMENT)	Office of Management and Budget Approval No. 29-RO184	
This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.	PAGE NO.	NO. OF PAGES

NAME OF OFFEROR	SUPPLIES AND/OR SERVICES TO BE FURNISHED	
Woods Hole Oceanographic Institution		
HOME OFFICE ADDRESS Woods Hole, MA 02543		
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED	TOTAL AMOUNT OF PROPOSAL $ 138,702	GOV'T SOLICITATION NO.

DETAIL DESCRIPTION OF COST ELEMENTS

1. DIRECT MATERIAL (Itemize on Exhibit A)			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
a. PURCHASED PARTS See Budget Detail			50,523		
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				50,523	
2. MATERIAL OVERHEAD[3] (Rate %X$ base=)					
3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
See Schedule A			22,723		
TOTAL DIRECT LABOR				22,723	
4. LABOR OVERHEAD (Specify Department or Cost Center)[3]	O.H. RATE	X BASE =	EST COST ($)		
See Schedule B					
Employee Benefits			10,206		
Laboratory Overhead			9,375		
TOTAL LABOR OVERHEAD				19,581	
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
TOTAL CONSULTANTS					
9. OTHER DIRECT COSTS (Itemize on Exhibit A)				30,376	
10. TOTAL DIRECT COST AND OVERHEAD				123,203	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.)[3]				8,894	Sched. B
12. ROYALTIES[4]					
13. TOTAL ESTIMATED COST				132,097	
14. FEE OR PROFIT				6,605	
15. TOTAL ESTIMATED COST AND FEE OR PROFIT				138,702	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE	
Maurice J. Tavares Sponsored Programs Administrator		
NAME OF FIRM Woods Hole Oceanographic Institution		DATE OF SUBMISSION 5/17/84

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL.NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST *($)*

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
Dom Tristaino, DCAA, 424 Trapelo Road, Waltham, MA 02154	617-894-2400 ext. 729

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify.)*: [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM 60 (10-71)

S C H E D U L E A

Salary Schedule

	Hours	Regular	Hours	Extra At Sea	Hours	Cruise Leave	Hours	Sea Duty Vacation	Hours	Overtime	Total Salaries
Drifters - Task I											
Limeburner, R.	280	$ 3,620									$ 3,620
Hess, F.	80	1,363									1,363
Task I Total		$ 4,983									$ 4,983
Moored Array - Task III											
Limeburner, R.	48	$ 639									$ 639
Dean, J.	48	997									997
Mills, C.	48	449									449
Mooring Technicians - TBA (10)	1,360	15,655									15,655
Task III Total		$17,740									$17,740
Project Total		$22,723									$22,723

Schedule B

SALARY AND RELATED COSTS INFORMATION

TOTAL SALARIES			$ 22,723
Employee Benefit Base:			
44.3 % of $11,882 = $ 5,263			
45.6 % of $10,841 = $ 4,943			
Total Employee Benefits			$ 10,206
TOTAL SALARIES AND EMPLOYEE BENEFITS			$ 32,929
Laboratory Cost:			
Salaries & Employee Benefits	$ 17,146		
Less Premium Pay	($ -)		
27.7 % of	$ 17,146	= $ 4,750	
Salaries & Employee Benefits	$ 15,784		
Less Premium Pay	($ -)		
29.3 % of	$ 15,784	= $ 4,625	
TOTAL LABORATORY COST			$ 9,375
Indirect Cost Base:			
Salaries & Employee Benefits	$ 17,146		
Less Premium Pay	($ -)		
27.2 % of	$ 17,146	= $ 4,664	
Salaries & Employee Benefits	$ 15,784		
Less Premium Pay	($ -)		
26.8 % of	$ 15,784	= $ 4,230	
TOTAL INDIRECT COST			$ 8,894

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 4 | NO. OF PAGES 5

NAME OF OFFEROR: Battelle Memorial Institute

HOME OFFICE ADDRESS: 505 King Avenue, Columbus, Ohio 43201

DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Columbus Laboratories

SUPPLIES AND/OR SERVICES TO BE FURNISHED: Modeling Transport of PCB and Metals in New Bedford Harbor

TASK 3000 - MODELING

TOTAL AMOUNT OF PROPOSAL: $ 732,548.

GOV'T SOLICITATION NO.:

DETAIL DESCRIPTION OF COST ELEMENTS

	ESTIMATED HOURS	RATE/HOUR	EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL (Itemize on Exhibit A)					
a. Materials, Supplies, and Miscellaneous					
b. SUBCONTRACTED ITEMS			675,159		
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				675,159	
2. MATERIAL OVERHEAD[3] (Rate %X$ base=)					
3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
Professional					
Nonprofessional					
TOTAL DIRECT LABOR					
4. LABOR OVERHEAD (Specify Department or Cost Center)[3]	O H RATE	X BASE =	EST COST ($)		
General Overhead					
Research Department Burden					
TOTAL LABOR OVERHEAD					
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
TOTAL CONSULTANTS					
9. OTHER DIRECT COSTS (Itemize on Exhibit A)					
10. TOTAL DIRECT COST AND OVERHEAD				675,159	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.)					
12. ROYALTIES[4]					
13. TOTAL ESTIMATED COST				675,159	
14. FEE OR PROFIT				57,389	
15. TOTAL ESTIMATED COST AND FEE OR PROFIT				732,548	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Robert N. Myers Contracting Officer	Robert N Myers

NAME OF FIRM	DATE OF SUBMISSION
Battelle Memorial Institute, Columbus Laboratories	May 18, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST *($)*

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
Defense Contract Audit Agency 505 King Avenue Columbus, Ohio 43201	(614)424-7800/FTS 976-7800

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

N/A [ ] YES [ ] NO *(If yes, identify.):* [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify.):*

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM 60 (10-71)

ESTIMATED COST DETAIL TASK 3000 - MODELING

DIRECT MATERIAL

a. Materials, Supplies, and Miscellaneous

Item Description	Quantity	Unit Price	Cost

Total $

b. Subcontracted Items

Item Description	Vendor	Cost
Food Chain Modeling	HydroQual	313,036
Hydrodynamics/Sediment Modeling	Battelle-Northwest	362,123.

Total $ 675,159.

Total Direct Material $ 675,159.

TRAVEL

Destination	No. Trips	No. Men	No. Days per Trip	Total No. Man-Days	Total Subsistence	Total Round Trip Fare	Ground Transport	Total Cost

Total Transportation ____ Total Subsistence ____ Total Travel $ ____

OTHER DIRECT COSTS

a. Use of Equipment

Item Description	Rate	No. Units	Cost

Total $ ________

b. Service Center/Special Facility Burdens

Area	Rate	Basis	Cost

Total $ ________

c. Duplicating and Photographic Services

Item Description	Cost

Total $ ________

d. Nuclear Services $ ________

e. Hot Laboratory Decontamination $ ________

f. Hazardous Materials Laboratory Decontamination $ ________

g. Cost of Facilities Capital $ ________

Total Other Direct Costs $ ________

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when *(i)* submission of cost or pricing data (see FPR 1-3.807-3) is required and *(ii)* substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. | NO. OF PAGES

NAME OF OFFEROR HYDROQUAL, INC.	SUPPLIES AND/OR SERVICES TO BE FURNISHED BEDFORD HARBOR FOOD WEB MODELING SUMMARY
HOME OFFICE ADDRESS 1 LETHBRIDGE PLAZA MAHWAH, NEW JERSEY 07430	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED MAHWAH	TOTAL AMOUNT OF PROPOSAL $ 313,035.72 — GOV'T SOLICITATION NO.

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL *(Itemize on Exhibit A)*					
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—*(1)* RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD[3] *(Rate %X$ base=)*					
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
PROJECT MANAGER--J.P. ST. JOHN	800.00	38.56	30848.00		
PROJECT CONSULTANT--J.P. CONNOLLY	520.00	30.88	16057.60		
SENIOR ENGINEER--J.J. FITZPATRICK	1416.00	25.32	35853.12		
PROJECT SCIENTIST--M.C. CASEY	2720.00	15.58	42377.60		
DRAFTSMAN--J.H. MCDONALD	320.00	12.10	3872.00		
TOTAL DIRECT LABOR				129008.32	
4. LABOR OVERHEAD *(Specify Department or Cost Center)*[3]	O.H. RATE	X BASE =	EST COST ($)		
DIRECT LABOR	1.0	129008.32	129008.32		
TOTAL LABOR OVERHEAD				129008.32	
5. SPECIAL TESTING *(Including field work at Government installations)*			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*					
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*			EST COST ($)		
a. TRANSPORTATION			3300.00		
b. PER DIEM OR SUBSISTENCE			1280.00		
TOTAL TRAVEL				4580.00	
8. CONSULTANTS *(Identify—purpose—rate)*			EST COST ($)		
J.M. O'CONNOR			7500.80		
TOTAL CONSULTANTS				7500.80	
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)* COMPUTER				19980.00	
10. *TOTAL DIRECT COST AND OVERHEAD*				290077.44	
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)*[3]					
12. ROYALTIES[4]					
13. *TOTAL ESTIMATED COST*				290077.44	
14. FEE OR PROFIT 8.5% on Items 3, 4, 7, and 8				22958.28	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*				313035.72	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

BEDFORD HARBOR FOOD WEB MODELING STUDY

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
JOHN P. ST. JOHN VICE PRESIDENT	

NAME OF FIRM	DATE OF SUBMISSION
HYDROQUAL, INC.	MAY 15, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST *($)*
	Expenses	
	Air Travel: 12 roundtrips to Duxbury, MA @ $125 airfare	$1,500
	2 roundtrips to Richmond, WA @ $900 airfare	1,800
	Per Diem: 16 mandays @ $80/day	1,280

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[x] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, NORTHERN NEW JERSEY BRANCH, LODI, NEW JERSEY	(201) 778-5577

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify.)*: [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[x] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM 60 (10-71)

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when *(i)* submission of cost or pricing data (see FPR 1-3.807-3) is required and *(ii)* substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 2

NAME OF OFFEROR
HYDROQUAL, INC.

HOME OFFICE ADDRESS
1 LETHBRIDGE PLAZA
MAHWAH, NEW JERSEY 07430

SUPPLIES AND/OR SERVICES TO BE FURNISHED
BEDFORD HARBOR
FOOD WEB MODELING
TASK 1: EVALUATE EXISTING DATA

DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED
MAHWAH

TOTAL AMOUNT OF PROPOSAL
$15,988.56

GOV'T SOLICITATION NO.

DETAIL DESCRIPTION OF COST ELEMENTS

1. DIRECT MATERIAL *(Itemize on Exhibit A)*			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—*(1)* RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD[1] *(Rate %X$ base=)*					
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
PROJECT MANAGER--J.P. ST. JOHN	32.00	38.56	1233.92		
PROJECT CONSULTANT--J.P. CONNOLLY	80.00	30.88	2470.40		
SENIOR ENGINEER--J.J. FITZPATRICK	56.00	25.32	1417.92		
PROJECT SCIENTIST--M.C. CASEY	96.00	15.58	1495.68		
TOTAL DIRECT LABOR				6617.92	
4. LABOR OVERHEAD *(Specify Department or Cost Center)*[1]	O.H. RATE	X BASE =	EST COST ($)		
DIRECT LABOR	1.0	6617.92	6617.92		
TOTAL LABOR OVERHEAD				6617.92	
5. SPECIAL TESTING *(Including field work at Government installations)*			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*					
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS *(Identify—purpose—rate)*			EST COST ($)		
J.M. O'CONNOR			1500.16		
TOTAL CONSULTANTS				1500.16	
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)*					
10. *TOTAL DIRECT COST AND OVERHEAD*				14736.00	
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)*[1]					
12. ROYALTIES[1]					
13. *TOTAL ESTIMATED COST*				14736.00	
14. FEE OR PROFIT 8.5% on Items 3, 4, and 8				1252.56	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*				15988.56	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

BEDFORD HARBOR FOOD WEB MODELING STUDY

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE	
JOHN P. ST. JOHN VICE PRESIDENT		
NAME OF FIRM HYDROQUAL, INC.		DATE OF SUBMISSION MAY 15, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST *($)*

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[x] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, NORTHERN NEW JERSEY BRANCH, LODI, NEW JERSEY	(201) 778-5577

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify.)*: [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[x] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM 60 (10-71)

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 2

NAME OF OFFEROR: HYDROQUAL, INC.	SUPPLIES AND/OR SERVICES TO BE FURNISHED: BEDFORD HARBOR FOOD WEB MODELING TASK 2: APPLY FOOD WEB MODEL
HOME OFFICE ADDRESS: 1 LETHBRIDGE PLAZA MAHWAH, NEW JERSEY 07430	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: MAHWAH	TOTAL AMOUNT OF PROPOSAL: $24,927.16 — GOV'T SOLICITATION NO.:

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL *(Itemize on Exhibit A)*					
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD[3] *(Rate %X$ base=)*					
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/ HOUR	EST COST ($)		
PROJECT MANAGER--J.P. ST. JOHN	40.00	38.56	1542.40		
PROJECT CONSULTANT--J.P. CONNOLLY	40.00	30.88	1235.20		
SENIOR ENGINEER--J.J. FITZPATRICK	120.00	25.32	3038.40		
PROJECT SCIENTIST--M.C. CASEY	320.00	15.58	4985.60		
TOTAL DIRECT LABOR				10801.60	
4. LABOR OVERHEAD *(Specify Department or Cost Center)*[1]	O.H RATE	X BASE =	EST COST ($)		
DIRECT LABOR	1.0	10801.60	10801.60		
TOTAL LABOR OVERHEAD				10801.60	
5. SPECIAL TESTING *(Including field work at Government installations)*			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*					
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS *(Identify—purpose—rate)*			EST COST ($)		
J.M. O'CONNOR			375.04		
TOTAL CONSULTANTS				375.04	
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)* COMPUTER				1080.00	
10. *TOTAL DIRECT COST AND OVERHEAD*				23058.24	
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)*[3]					
12. ROYALTIES[4]					
13. *TOTAL ESTIMATED COST*				23058.24	
14. FEE OR PROFIT 8.5% on Items 3, 4, and 8				1868.15	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*				24926.39	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

BEDFORD HARBOR FOOD WEB MODELING STUDY

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE
JOHN P. ST. JOHN
VICE PRESIDENT

SIGNATURE

NAME OF FIRM
HYDROQUAL, INC.

DATE OF SUBMISSION
MAY 15, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST ($)

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

☒ YES ☐ NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL
DCAA, NORTHERN NEW JERSEY BRANCH, LODI, NEW JERSEY

TELEPHONE NUMBER/EXTENSION
(201) 778-5577

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify.)*: ☐ ADVANCE PAYMENTS ☐ PROGRESS PAYMENTS OR ☐ GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

☒ YES ☐ NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM 60 (10-71)

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when *(i)* submission of cost or pricing data (see FPR 1-3.807-3) is required and *(ii)* substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 2

NAME OF OFFEROR HYDROQUAL, INC.	SUPPLIES AND/OR SERVICES TO BE FURNISHED BEDFORD HARBOR FOOD WEB MODELING TASK 3: PRELIMINARY MODEL CALIBRATION
HOME OFFICE ADDRESS 1 LETHBRIDGE PLAZA MAHWAH, NEW JERSEY 07430	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED MAHWAH	TOTAL AMOUNT OF PROPOSAL $32,091.17 — GOV'T SOLICITATION NO.

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL *(Itemize on Exhibit A)*					
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD[1] *(Rate %X$ base=)*					
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
PROJECT MANAGER--J.P. ST. JOHN	80.00	38.56	3084.80		
PROJECT CONSULTANT--J.P. CONNOLLY	40.00	30.88	1235.20		
SENIOR ENGINEER--J.J. FITZPATRICK	160.00	25.32	4051.20		
PROJECT SCIENTIST--M.C. CASEY	320.00	15.58	4985.60		
TOTAL DIRECT LABOR				13356.80	
4. LABOR OVERHEAD *(Specify Department or Cost Center)*[1]	O.H. RATE	X BASE =	EST COST ($)		
DIRECT LABOR	1.0	13356.80	13356.80		
TOTAL LABOR OVERHEAD				13356.80	
5. SPECIAL TESTING *(Including field work at Government installations)*			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*					
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS *(Identify—purpose—rate)*			EST COST ($)		
J.M. O'CONNOR			375.04		
TOTAL CONSULTANTS				375.04	
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)* COMPUTER				2700.00	
10. *TOTAL DIRECT COST AND OVERHEAD*				29788.64	
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)*[1]					
12. ROYALTIES[1]					
13. *TOTAL ESTIMATED COST*				29788.64	
14. FEE OR PROFIT 8.5% on Items 3, 4, and 8				2302.53	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*				32091.17	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

BEDFORD HARBOR FOOD WEB MODELING STUDY

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE	
JOHN P. ST. JOHN VICE PRESIDENT	J. P. St. J.	
NAME OF FIRM HYDROQUAL, INC.		DATE OF SUBMISSION MAY 15, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST *($)*

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[x] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, NORTHERN NEW JERSEY BRANCH, LODI, NEW JERSEY	(201) 778-5577

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify.)*: [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[x] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes

OPTIONAL FORM 60 (10-71)

CONTRACT PRICING PROPOSAL (*RESEARCH AND DEVELOPMENT*)	Office of Management and Budget Approval No. 29-RO184	
This form is for use when (*i*) submission of cost or pricing data (see FPR 1-3.807-3) is required and (*ii*) substitution for the Optional Form 59 is authorized by the contracting officer.	PAGE NO. 1	NO. OF PAGES 2

NAME OF OFFEROR	SUPPLIES AND/OR SERVICES TO BE FURNISHED	
HYDROQUAL, INC.	BEDFORD HARBOR FOOD WEB MODELING TASK 4: EVALUATE NEW DATA AND DETAILED MODEL CALIBRATION	
HOME OFFICE ADDRESS 1 LETHBRIDGE PLAZA MAHWAH, NEW JERSEY 07430		
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED	TOTAL AMOUNT OF PROPOSAL	GOV'T SOLICITATION NO.
MAHWAH	$ 137,679.81	

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL (*Itemize on Exhibit A*)					
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (*At other than cost*)					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD[1] (*Rate %X$ base=*)					
3. DIRECT LABOR (*Specify*)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
PROJECT MANAGER--J.P. ST. JOHN	336.00	38.56	12956.16		
PROJECT CONSULTANT--J.P. CONNOLLY	224.00	30.88	6917.12		
SENIOR ENGINEER--J.J. FITZPATRICK	648.00	25.32	16407.36		
PROJECT SCIENTIST--M.C. CASEY	1288.00	15.58	20067.04		
TOTAL DIRECT LABOR				56347.68	
4. LABOR OVERHEAD (*Specify Department or Cost Center*)[1]	O.H. RATE	X BASE =	EST COST ($)		
DIRECT LABOR	1.0	56347.68	56347.68		
TOTAL LABOR OVERHEAD				56347.68	
5. SPECIAL TESTING (*Including field work at Government installations*)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (*If direct charge*) (*Itemize on Exhibit A*)					
7. TRAVEL (*If direct charge*) (*Give details on attached Schedule*)			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS (*Identify—purpose—rate*)			EST COST ($)		
J.M. O'CONNOR			3000.32		
TOTAL CONSULTANTS				3000.32	
9. OTHER DIRECT COSTS (*Itemize on Exhibit A*) COMPUTER				12150.00	
10. *TOTAL DIRECT COST AND OVERHEAD*				127845.68	
11. GENERAL AND ADMINISTRATIVE EXPENSE (*Rate % of cost element Nos.*)[1]					
12. ROYALTIES[4]					
13. *TOTAL ESTIMATED COST*				127845.68	
14. FEE OR PROFIT 8.5% on Items 3, 4, and 8				9834.13	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*				137679.81	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

BEDFORD HARBOR FOOD WEB MODELING STUDY

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE	
JOHN P. ST. JOHN VICE PRESIDENT		
NAME OF FIRM HYDROQUAL, INC.		DATE OF SUBMISSION MAY 15, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST ($)

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, NORTHERN NEW JERSEY BRANCH, LODI, NEW JERSEY	(201) 778-5577

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify.):* [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify.):*

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes

OPTIONAL FORM 60 (10-71)

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when *(i)* submission of cost or pricing data (see FPR 1-3.807-3) is required and *(ii)* substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 2

NAME OF OFFEROR: HYDROQUAL, INC.	SUPPLIES AND/OR SERVICES TO BE FURNISHED: BEDFORD HARBOR FOOD WEB MODELING TASK 5: EVALUATE REMEDIAL ACTIONS
HOME OFFICE ADDRESS: 1 LETHBRIDGE PLAZA MAHWAH, NEW JERSEY 07430	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: MAHWAH	TOTAL AMOUNT OF PROPOSAL: $ 47,000.03 — GOV'T SOLICITATION NO.:

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL *(Itemize on Exhibit A)*					
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—*(1)* RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD[3] *(Rate %X$ base=)*					
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
PROJECT MANAGER--J.P. ST. JOHN	120.00	38.56	4627.20		
PROJECT CONSULTANT--J.P. CONNOLLY	40.00	30.88	1235.20		
SENIOR ENGINEER--J.J. FITZPATRICK	240.00	25.32	6076.80		
PROJECT SCIENTIST--M.C. CASEY	480.00	15.58	7478.40		
TOTAL DIRECT LABOR				19417.60	
4. LABOR OVERHEAD *(Specify Department or Cost Center)*[3]	O.H. RATE	X BASE =	EST COST ($)		
DIRECT LABOR	1.0	19417.60	19417.60		
TOTAL LABOR OVERHEAD				19417.60	
5. SPECIAL TESTING *(Including field work at Government installations)*			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*					
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS *(Identify—purpose—rate)*			EST COST ($)		
J.M. O'CONNOR			750.08		
TOTAL CONSULTANTS				750.08	
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)* COMPUTER				4050.00	
10. *TOTAL DIRECT COST AND OVERHEAD*				43635.28	
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)*[3]					
12. ROYALTIES[4]					
13. *TOTAL ESTIMATED COST*				43635.28	
14. FEE OR PROFIT 8.5% on Items 3, 4, and 8				3364.75	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*				47000.03	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

BEDFORD HARBOR FOOD WEB MODELING STUDY

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
JOHN P. ST. JOHN VICE PRESIDENT	
NAME OF FIRM HYDROQUAL, INC.	DATE OF SUBMISSION MAY 15, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST ($)

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[x] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, NORTHERN NEW JERSEY BRANCH, LODI, NEW JERSEY	(201) 778-5577

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify.)*: [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [x] NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[x] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM 60 (10-71)

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when *(i)* submission of cost or pricing data (see FPR 1-3.807-3) is required and *(ii)* substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 1 | NO. OF PAGES 2

NAME OF OFFEROR: HYDROQUAL, INC.	SUPPLIES AND/OR SERVICES TO BE FURNISHED: BEDFORD HARBOR FOOD WEB MODELING TASK 6: MEETINGS AND REPORTS
HOME OFFICE ADDRESS: 1 LETHBRIDGE PLAZA MAHWAH, NEW JERSEY 07430	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: MAHWAH	TOTAL AMOUNT OF PROPOSAL: $55,349.76 — GOV'T SOLICITATION NO.

DETAIL DESCRIPTION OF COST ELEMENTS

			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
1. DIRECT MATERIAL *(Itemize on Exhibit A)*					
a. PURCHASED PARTS					
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS *(At other than cost)*					
TOTAL DIRECT MATERIAL					
2. MATERIAL OVERHEAD[1] *(Rate %X$ base=)*					
3. DIRECT LABOR *(Specify)*	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
PROJECT MANAGER--J.P. ST. JOHN	192.00	38.56	7403.52		
PROJECT CONSULTANT--J.P. CONNOLLY	96.00	30.88	2964.48		
SENIOR ENGINEER--J.J. FITZPATRICK	192.00	25.32	4861.44		
PROJECT SCIENTIST--M.C. CASEY	216.00	15.58	3365.28		
DRAFTSMAN--J.H. MCDONALD	320.00	12.10	3872.00		
TOTAL DIRECT LABOR				22466.72	
4. LABOR OVERHEAD *(Specify Department or Cost Center)*[1]	O.H. RATE	X BASE =	EST COST ($)		
DIRECT LABOR	1.0	22466.72	22466.72		
TOTAL LABOR OVERHEAD				22466.72	
5. SPECIAL TESTING *(Including field work at Government installations)*			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT *(If direct charge) (Itemize on Exhibit A)*					
7. TRAVEL *(If direct charge) (Give details on attached Schedule)*			EST COST ($)		
a. TRANSPORTATION			3300.00		
b. PER DIEM OR SUBSISTENCE			1280.00		
TOTAL TRAVEL				4580.00	
8. CONSULTANTS *(Identify—purpose—rate)*			EST COST ($)		
J.M. O'CONNOR			1500.16		
TOTAL CONSULTANTS				1500.16	
9. OTHER DIRECT COSTS *(Itemize on Exhibit A)*					
10. *TOTAL DIRECT COST AND OVERHEAD*				51013.60	
11. GENERAL AND ADMINISTRATIVE EXPENSE *(Rate % of cost element Nos.)*[1]					
12. ROYALTIES[1]					
13. *TOTAL ESTIMATED COST*				51013.60	
14. FEE OR PROFIT 8.5% on Items 3, 4, 7, and 8				4336.16	
15. *TOTAL ESTIMATED COST AND FEE OR PROFIT*				55349.76	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

BEDFORD HARBOR FOOD WEB MODELING STUDY

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE	
JOHN P. ST. JOHN VICE PRESIDENT		
NAME OF FIRM HYDROQUAL, INC.		DATE OF SUBMISSION MAY 15, 1984

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST *($)*
	Expenses	
	Air Travel: 12 roundtrips to Duxbury, MA @ $125 airfare	$1,500
	2 roundtrips to Richmond, WA @ $900 airfare	1,800
	Per Diem: 16 mandays @ $80/day	1,280

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

☒ YES ☐ NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
DCAA, NORTHERN NEW JERSEY BRANCH, LODI, NEW JERSEY	(201) 778-5577

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify.):* ☐ ADVANCE PAYMENTS ☐ PROGRESS PAYMENTS OR ☐ GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

☐ YES ☒ NO *(If yes, identify.):*

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

☒ YES ☐ NO *(If no, explain on reverse or separate page)*

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget
Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. | NO. OF PAGES

NAME OF OFFEROR Battelle Memorial Institute Pacific Northwest Laboratories	SUPPLIES AND/OR SERVICES TO BE FURNISHED BNW No. 2311106548
HOME OFFICE ADDRESS P. O. Box 999 Richland, WA 99352	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED Pacific Northwest Laboratories, Richland	TOTAL AMOUNT OF PROPOSAL $ 392,900 GOV'T SOLICITATION NO.

DETAIL DESCRIPTION OF COST ELEMENTS

1. DIRECT MATERIAL (Itemize on Exhibit A)			EST COST ($)	TOTAL EST COST[1]	REFERENCE[2]
a. PURCHASED PARTS			8,942		
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				8,942	Ex. A, B
2. MATERIAL OVERHEAD[3] (Rate %X$ base=)					
3. DIRECT LABOR (Specify)	ESTIMATED ~~man-months~~ hours	RATE/HOUR	EST COST ($)		
Senior Research Staff	2,647		100,084		
Research Scientist/Engineers	1,830		36,245		
Secretarial/Clerical	288		4,466		
TOTAL DIRECT LABOR				140,795	Ex. A,B,C
4. LABOR OVERHEAD (Specify Department or Cost Center)[3]	O.H. RATE	X BASE =	EST COST ($)		
Research Department Management Cost	.30	140,795	42,237		
TOTAL LABOR OVERHEAD				42,237	Ex. A,B
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION			13,350		
b. PER DIEM OR SUBSISTENCE			3,375		
TOTAL TRAVEL				16,725	Ex. A,B,D
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
TOTAL CONSULTANTS					
9. OTHER DIRECT COSTS (Itemize on Exhibit A)				19,671	Ex. A,B
10. TOTAL DIRECT COST AND OVERHEAD				228,370	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate 95% of cost element Nos. 3)[3]				133,753	Ex. A,B
12. ROYALTIES[4]					
13. TOTAL ESTIMATED COST				362,123	
14. FEE				30,777	
15. TOTAL ESTIMATED COST AND FEE				392,900	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
5060-101

This proposal is submitted for use in connection with and in response to *(Describe RFP, etc.)*

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
JEFFREY K. ACE CONTRACTING OFFICER	Jeffrey K. Ace

NAME OF FIRM	DATE OF SUBMISSION
Battelle Memorial Institute Pacific Northwest Laboratories	5/16/84

EXHIBIT A—SUPPORTING SCHEDULE *(Specify. If more space is needed, use reverse)*

COST EL NO.	ITEM DESCRIPTION *(See footnote 5)*	EST COST *($)*
	See Attached Exhibit A, B, C, D	

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO *(If yes, identify below.)*

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL		TELEPHONE NUMBER/EXTENSION
DOE, DOE HQ Office of Inspector General	William Peck, Acting Inspector General/Audit	(509) 376-2039

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT? Under Existing Use Permit DE-AC06-76RLO 1831

[X] YES [ ] NO *(If yes, identify on reverse or separate page)*

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

[X] YES [ ] NO *(If yes, identify.)*: [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT *(Or, do you have any independently financed (IR&D) projects)* FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO *(If yes, identify.)*:

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO *(If no, explain on reverse or separate page)*

See Reverse for Instructions and Footnotes OPTIONAL FORM 60 (10-71)

N65482S

EXHIBIT A
SUPPORTING SCHEDULES AND INFORMATION

COST BREAKDOWN BY TASK	EXHIBIT B
BREAKDOWN OF LABOR HOURS	EXHIBIT C
TRAVEL DETAIL	EXHIBIT D
INDIRECT COST RATES FOR FY 1984	ATTACHMENT #1

COST ELEMENT NO.	INFORMATION
1.	**DIRECT MATERIALS** MATERIAL AND/OR SUBCONTRACT COST INCLUDES A PROVISION FOR THE COST OF PLACEMENT AND ADMINISTRATION ALLOCATED AT PREDETERMINED RATES.
3.	**DIRECT LABOR** ESTIMATED AT CURRENT INDIVIDUAL CHARGE OUT RATES. BNW'S NORMAL PROCEDURE IS TO HAVE ALL SALARY ACTIONS EFFECTIVE APRIL 1 OF EACH YEAR THEREFORE THE LABOR RATES HAVE BEEN ESCALATED AT 6 PERCENT ANNUALLY AS OF APRIL 1, 1985.
4.	**LABOR OVERHEAD** ALLOCATED AT CURRENTLY APPROVED PROVISIONAL RATE OF 30.0 PERCENT OF RESEARCH PERSONNEL DIRECT STAFF LABOR. (SEE ATTACHMENT #1)
7	**TRAVEL** BNW TRAVEL POLICY PROVIDES REIMBURSEMENT OF ACTUAL AND REASONABLE TRAVEL EXPENSES. THIS POLICY HAS BEEN APPROVED BY THE U.S. DEPARTMENT OF ENERGY, RICHLAND OPERATION OFFICE
9	**OTHER DIRECT COSTS** **FACILITY AND EQUIPMENT USAGE** FACILITY AND EQUIPMENT USAGE REPRESENTS COSTS INCURRED BY A DEPARTMENT IN SUPPORT OF RESEARCH FACILITIES WHICH ARE IMPRACTICAL TO ALLOCATE TO INDIVIDUAL CONTRACTS. INCLUDED IN THIS COST CATEGORY ARE LABORATORY SUPPLIES, SMALL TOOLS, LAUNDRY, DECONTAMINATION/WASTE DISPOSAL, MAINTENANCE EXPENSES AND EXPENSES ASSOCIATED WITH BATTELLE-OWNED EQUIPMENT WITH A FIRST COST OF LESS THAN $50,000 SUCH AS DEPRECIATION, MAINTENANCE, TAXES AND INSURANCE. THESE COSTS ARE ACCUMULATED IN AN INTERMEDIATE COST POOL AND ARE ALLOCATED TO COST OBJECTIVES AT A PREDETERMINED RATE PER DIRECT LABOR HOUR. **SPECIAL PURPOSE EQUIPMENT** **BATTELLE-OWNED EQUIPMENT** COSTS ASSOCIATED WITH MAJOR ITEMS/SYSTEMS OF BATTELLE-OWNED EQUIPMENT (IN EXCESS OF $50,000 FIRST COST) ARE ACCUMULATED IN AN INTERMEDIATE COST POOL AND ALLOCATED AT A PREDETERMINED USAGE RATE FOR EACH ITEM. **QUALITY ASSURANCE ASSESSMENT** TO MEET BNW'S STANDARDS OF QUALITY, RELIABILITY AND SAFETY, BNW MAINTAINS A QUALITY ASSURANCE SYSTEM WITH SPECIFIC INDIVIDUALS ASSIGNED TO PERFORM QUALITY ASSURANCE REVIEW. THE COST OF THIS ACTIVITY IS ACCUMULATED IN AN INTERMEDIATE COST POOL AND ALLOCATED AT A PREDETERMINED RATE PER DIRECT LABOR DOLLAR. **OTHER SERVICE CENTER COST (REPORT PREPARATION, GRAPHICS, DUPLICATING ETC.)** THE COST OF CERTAIN CENTRALIZED SERVICES SUCH AS GRAPHICS, DUPLICATING, COMPUTER, ETC., ARE ACCUMULATED IN INTERMEDIATE COST POOLS AND ARE ALLOCATED BASED ON THE ACTUAL USAGE OF THE SERVICES PROVIDED BY EACH CENTER.
11	**GENERAL & ADMINISTRATIVE EXPENSE** ALLOCATED AT CURRENTLY APPROVED PROVISIONAL RATE OF 95.0 PERCENT OF DIRECT STAFF LABOR. (SEE ATTACHMENT #1)

N654820

EXHIBIT B
COST BREAKDOWN BY TASK

COST EL. NO.	DIRECT MATERIALS	TASK 1	TASK 2	TASK 3	TASK 4	TASK 5	TOTAL EST. COST ($)
	MATERIALS - TAPE			8942			8942
	TOTAL DIRECT MATERIALS	0	0	8942	0	0	8942
3.	DIRECT LABOR						
	SENIOR RESEARCH STAFF	10597	20673	15495	42267	11052	100084
	RESEARCH SCIENTIST/ENGINEERS		5811	1206	26882	2346	36245
	SECRETARIAL/CLERICAL	667	257	733	469	2340	4466
	TOTAL DIRECT LABOR	11264	26741	17434	69618	15738	140795
4.	LABOR OVERHEAD						
	RESEARCH DEPT. MGMT. COST	3379	8022	5230	20885	4721	42237
	TOTAL LABOR OVERHEAD	3379	8022	5230	20885	4721	42237
7.	TRAVEL						
	TRANSPORTATION	1780	1780	3560	3560	2670	13350
	SUBSISTENCE	450	450	900	900	675	3375
	TOTAL TRAVEL	2230	2230	4460	4460	3345	16725
9	OTHER DIRECT COSTS						
	FACILITY & EQUIPMENT USAGE	639	1562	782	4085	966	8034
	BNW EQUIPMENT			1995			1995
	QUALITY ASSURANCE	180	427	278	1113	251	2249
	WORD PROCESSING	720	250	712	429	2504	4615
	GRAPHICS	430	150	428	270	1500	2778
	TOTAL OTHER DIRECT COSTS	1969	2389	4195	5897	5221	19671
10.	TOTAL DIRECT COST & OVERHEAD	18842	39382	40261	100860	29025	228370
11	GENERAL & ADMINISTRATIVE EXPENSE	10700	25403	16562	66137	14951	133753
13.	TOTAL ESTIMATED COST	29542	64785	56823	166997	43976	362123
14.	FEE	2511	5506	4829	14194	3737	30777
15.	TOTAL ESTIMATED COST & FEE	32053	70291	61652	181191	47713	392900

EXHIBIT C
BREAKDOWN OF LABOR HOURS

	TASK 1	TASK 2	TASK 3	TASK 4	TASK 5	TOTAL HOURS
SENIOR RESEARCH STAFF	291	540	432	1097	287	2647
RESEARCH SCIENTIST/ENGINEER		280	78	1356	116	1830
SECRETARIAL/CLERICAL	44	17	47	30	150	288
TOTAL HOURS	335	837	557	2483	553	4765

EXHIBIT D
TRAVEL DETAIL

DESTINATION	#STAFF	#TRIPS	#DAYS	AIRFARE	CAR RENTAL	SUBSIS-TENCE	TOTAL ($)
TASK 1							
BOSTON	1	2	6	1600	180	450	2230
SUBTOTAL				1600	180	450	2230
TASK 2							
BOSTON	1	2	6	1600	180	450	2230
SUBTOTAL				1600	180	450	2230
TASK 3							
BOSTON	1	4	12	3200	360	900	4460
SUBTOTAL				3200	360	900	4460
TASK 4							
BOSTON	1	4	12	3200	360	900	4460
SUBTOTAL				3200	360	900	4460
TASK 5							
BOSTON	1	3	9	2400	270	675	3345
SUBTOTAL				2400	270	675	3345
TOTAL TRAVEL				12000	1350	3375	16725

ATTACHMENT #1

xc: AFJ (w/enc.)
CDF
RPM
JJF

3/14/84
sr

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

RECEIVED
MAR 14 1984
A.F. [illegible]NSTON

MAR 12 1984

Director
Pacific Northwest Laboratory
Richland, Washington

Dear Sir:

TRANSMITTAL OF OFFICE OF INSPECTOR GENERAL AUDIT REPORT ON FY 1984 PROVISIONAL INDIRECT RATES

The Office of Inspector General (OIG) has completed its review of your proposed provisional indirect rates for FY 1984, applicable to Contract No. DE-AC06-76RL01831. The proposed rates were found to be acceptable for bidding and provisional billing purposes.

Enclosed for your files is a copy of the subject OIG Audit Report. Indirect rate proposals applicable to Contract No. DE-AC06-76RL01831 should be submitted to the OIG with a copy to DOE-RL.

If you require further information regarding the subject matter, please contact Mr. Garry Amidan on 6-8993.

Very truly yours,

Robert D. Larson

Robert D. Larson, Director
Procurement Division

FIN:GLA

Enclosure:
Audit Report

RECEIVED
MAR 14 1984
D. E. OLESEN

OFFICE OF INSPECTOR GENERAL
OFFICE OF AUDITS
WESTERN REGION
Albuquerque, New Mexico 87106

REVIEW OF FISCAL YEAR 1984 PROVISIONAL INDIRECT COST RATES SUBMITTED BY BATTELLE NORTHWEST RICHLAND, WASHINGTON

Audit Report No.: WR-C-84-8

February 29, 1984

PURPOSE AND SCOPE OF AUDIT

In response to a request from the Richland Operations Office, we reviewed Battelle Northwest's (BNW) Fiscal Year 1984 provisional indirect cost rates for use in pricing and provisional billing. BNW provides scientific research and other services for commercial and government (mostly non-DOE) clients.

The audit was done according to generally accepted Government auditing standards for financial and compliance audits and included such tests of the contractor's data and records and such other auditing procedures as we considered necessary in the circumstances. The cost principles contained in Federal Procurement Regulations, Defense Acquisition Regulations, and Department of Health and Human Services Cost Principles were used as criteria in the determination of acceptable costs.

This report may not be released to any Federal agency outside the requesting Department without the approval of the Headquarters, Office of Audits, except or an agency involved in negotiating or administering the contract.

CIRCUMSTANCES AFFECTING THE AUDIT

BNW requested that their 1984 provisional rates be approved so they could continue to bid on Government proposals and receive progress payments on ongoing Government work. Due to an extensive audit backlog and BNW's past history of actual costs exceeding provisional rates, we agreed to do a limited review of BNW's proposed provisional rates on the basis of consistency with audited 1982 rates, provisional rates approved for 1983, and preliminary 1983 actual rates.

RESULT OF AUDIT

We found BNW's Fiscal Year cost estimates to be consistent with prior years and in excess of BNW's proposed provisional billing rates. Therefore, we determined that the provisional rates shown on the attached Exhibit A are acceptable for bidding and provisional billing expenses.

General and Administrative (G&A) and Department Management Costs (DMC) are allocated on direct staff labor. It has been BNW's past practice to limit final billed rates to the combined G&A and DMC provisional rate even though their combined G&A and DMC actual rate exceeded the provisional rate.

An exit conference was held with BNW's Manager of Contract Finance on January 16, 1984. He agreed with the rates as shown on Exhibit A.

CONCLUSIONS AND RECOMMENDATIONS

BNW's Fiscal Year 1984 provisional rates are consistent with prior years approved rates and are acceptable. We recommend they be approved for use in bidding and interim billing purposes.

Office of Inspector General

STATEMENT OF CONTRACTOR'S PROPOSED PROVISIONAL
RATES AND RESULTS OF REVIEW
BATTELLE NORTHWEST
FISCAL YEAR 1984

Description	Contractor's Proposed Rates	Results of Review: Rate Questioned	Results of Review: Recommended Rates	
Department Mgmt. Cost (DMC)				Note 1
- Research Components	30.0%	-	30.0%	
- Service Components	22.5%	-	22.5%	
- Other Staff Components	25.0%	-	25.0%	
General & Administrative (G&A)				Note 2
Contracts	95.0%	-	95.0%	
Cost Sharing Contracts				
- NSF and DHHS	95.0%	-	95.0%	
- Other FAR Covered	105.0%	-	105.0%	
- Other DAR Covered	105.0%	-	105.0%	
Cost of Facility Capital (CAS 414)	15.0%	-	15.0%	Note 3

Explanatory Notes:

1. DMC is allocated on the basis of direct staff labor, including salaries and wages and fringe benefit costs of staff assigned to the organizational components represented by the applicable cost pool.

2. G&A is allocated on the basis of direct staff labor, including salaries and wages and fringe benefits.

3. CAS 414 is allocated on the basis of direct staff labor, including salaries and wages and fringe benefits, but applies only to direct staff labor performed in BNW owned facilities.

CONTRACT PRICING PROPOSAL
(RESEARCH AND DEVELOPMENT)

Office of Management and Budget Approval No. 29-RO184

This form is for use when (i) submission of cost or pricing data (see FPR 1-3.807-3) is required and (ii) substitution for the Optional Form 59 is authorized by the contracting officer.

PAGE NO. 5 | NO. OF PAGES 5

NAME OF OFFEROR: Battelle Memorial Institute	SUPPLIES AND/OR SERVICES TO BE FURNISHED: Modeling Transport of PCB and Metals in New Bedford Harbor TASK 4000 - LAB ANALYSIS
HOME OFFICE ADDRESS: 505 King Avenue, Columbus, Ohio 43201	
DIVISION(S) AND LOCATION(S) WHERE WORK IS TO BE PERFORMED: Columbus Laboratories	TOTAL AMOUNT OF PROPOSAL: $ 121,805. — GOV'T SOLICITATION NO.

DETAIL DESCRIPTION OF COST ELEMENTS

1. DIRECT MATERIAL (Itemize on Exhibit A)			EST COST ($)	TOTAL EST COST	REFERENCE
a. Materials, Supplies, and Miscellaneous			8250		
b. SUBCONTRACTED ITEMS					
c. OTHER—(1) RAW MATERIAL					
(2) YOUR STANDARD COMMERCIAL ITEMS					
(3) INTERDIVISIONAL TRANSFERS (At other than cost)					
TOTAL DIRECT MATERIAL				8,250	
2. MATERIAL OVERHEAD (Rate %X$ base =)					
3. DIRECT LABOR (Specify)	ESTIMATED HOURS	RATE/HOUR	EST COST ($)		
Professional	1111	29.97	33301		
Nonprofessional	821	13.31	10926		
TOTAL DIRECT LABOR				44,227	
4. LABOR OVERHEAD (Specify Department or Cost Center)	O H RATE	X BASE =	EST COST ($)		
General Overhead	81	44227	35825		
Research Department Burden	33	44227	14595		
TOTAL LABOR OVERHEAD				50,420	
5. SPECIAL TESTING (Including field work at Government installations)			EST COST ($)		
TOTAL SPECIAL TESTING					
6. SPECIAL EQUIPMENT (If direct charge) (Itemize on Exhibit A)					
7. TRAVEL (If direct charge) (Give details on attached Schedule)			EST COST ($)		
a. TRANSPORTATION					
b. PER DIEM OR SUBSISTENCE					
TOTAL TRAVEL					
8. CONSULTANTS (Identify—purpose—rate)			EST COST ($)		
TOTAL CONSULTANTS					
9. OTHER DIRECT COSTS (Itemize on Exhibit A)				9,365	
10. TOTAL DIRECT COST AND OVERHEAD				112,262	
11. GENERAL AND ADMINISTRATIVE EXPENSE (Rate % of cost element Nos.)					
12. ROYALTIES					
13. TOTAL ESTIMATED COST				112,262	
14. FEE OR PROFIT				9,543	
15. TOTAL ESTIMATED COST AND FEE OR PROFIT				121,805	

OPTIONAL FORM 60
October 1971
General Services Administration
FPR 1-16.806
1060-101

This proposal is submitted for use in connection with and in response to (Describe RFP, etc.)

and reflects our best estimates as of this date, in accordance with the Instructions to Offerors and the Footnotes which follow.

TYPED NAME AND TITLE	SIGNATURE
Robert N. Myers Contracting Officer	Robert N Myers

NAME OF FIRM	DATE OF SUBMISSION
Battelle Memorial Institute, Columbus Laboratories	May 18, 1984

EXHIBIT A—SUPPORTING SCHEDULE (Specify. If more space is needed, use reverse)

COST EL NO.	ITEM DESCRIPTION (See footnote 5)	EST COST ($)

I. HAS ANY EXECUTIVE AGENCY OF THE UNITED STATES GOVERNMENT PERFORMED ANY REVIEW OF YOUR ACCOUNTS OR RECORDS IN CONNECTION WITH ANY OTHER GOVERNMENT PRIME CONTRACT OR SUBCONTRACT WITHIN THE PAST TWELVE MONTHS?

[X] YES [ ] NO (If yes, identify below.)

NAME AND ADDRESS OF REVIEWING OFFICE AND INDIVIDUAL	TELEPHONE NUMBER/EXTENSION
Defense Contract Audit Agency 505 King Avenue Columbus, Ohio 43201	(614)424-7800/FTS 976-7800

II. WILL YOU REQUIRE THE USE OF ANY GOVERNMENT PROPERTY IN THE PERFORMANCE OF THIS PROPOSED CONTRACT?

[ ] YES [X] NO (If yes, identify on reverse or separate page)

III. DO YOU REQUIRE GOVERNMENT CONTRACT FINANCING TO PERFORM THIS PROPOSED CONTRACT?

N/A [ ] YES [ ] NO (If yes, identify.): [ ] ADVANCE PAYMENTS [ ] PROGRESS PAYMENTS OR [ ] GUARANTEED LOANS

IV. DO YOU NOW HOLD ANY CONTRACT (Or, do you have any independently financed (IR&D) projects) FOR THE SAME OR SIMILAR WORK CALLED FOR BY THIS PROPOSED CONTRACT?

[ ] YES [X] NO (If yes, identify.):

V. DOES THIS COST SUMMARY CONFORM WITH THE COST PRINCIPLES SET FORTH IN AGENCY REGULATIONS?

[X] YES [ ] NO (If no, explain on reverse or separate page)

See Reverse for Instructions and Footnotes

OPTIONAL FORM 60 (10-71)

ESTIMATED COST DETAIL

DIRECT MATERIAL

a. Materials, Supplies, and Miscellaneous

Item Description	Quantity	Unit Price	Cost
Glassware, Misc. Chem., Teflon jars, Solvents,			
Acids, Tubing, Misc. Supplies			8,250.
		Total $	8,250.

b. Subcontracted Items

Item Description	Vendor	Cost
	Total $	

Total Direct Material $ 8,250.

TRAVEL

Destination	No. Trips	No. Men	No. Days per Trip	Total No. Man-Days	Total Subsistence	Total Round Trip Fare	Ground Transport	Total Cost

Total Transportation ______ Total Subsistence ______ Total Travel $ ______

OTHER DIRECT COSTS

a. Use of Equipment

Item Description	Rate	No. Units	Cost
General Support Facility - Dept 500	11%	44,227.	4,865.
Chemistry Facility	10/Hr	450	4,500.
		Total $	9,365.

b. Service Center/Special Facility Burdens

Area	Rate	Basis	Cost
		Total $	

c. Duplicating and Photographic Services

Item Description	Cost
Total $	

d. Nuclear Services $

e. Hot Laboratory Decontamination $

f. Hazardous Materials Laboratory Decontamination $

g. Cost of Facilities Capital $

Total Other Direct Costs $ 9,365.

6. LITERATURE CITED

Albro, D.W., J.K. Haseman, T.A. Clemmer and B.J. Corbett. 1977. Identification of the individual polychlorinated biphenyls in a mixture by gas-liquid chromatography. J. Chromatography 136:147-153.

Ballschmitter, K. and M. Zell. 1980. Analysis of polychlorinated biphenyls (PCB) by glass capillary gas chromatography. Fresnius Z. Anal. Chem. 301:20-31.

Batley, G.E. and D. Gardner. 1978. A study of copper, lead and cadmium speciation in some estuarine and coastal marine waters. Est. & Coastl. Mar. Sci. 7:59-70.

Bayne, B.L., Ed. Marine Mussels: Their Ecology and Physiology. International Biological Programme 10. Cambridge University Press, Cambridge.

Bigelow, H.B. and W.C. Schroeder. Fishes of the Gulf of Maine, First Revision (Fishery Bulletin No. 74: Fishery Bulletin of the Fish and Wildlife Service - Vol. 53. (Contribution No. 592, Woods Hole Oceanographic Institution). U.S. Government Printing Office, Washington, D.C.

Boehm, P.D. 1983. Coupling of particulate organic pollutants between the estuary and continental shelf and the sediments and water column in the New York Bight region. Can. J. Fish. Aquatic Sci. 40:Suppl 2:262-276.

Boutwell, S.M. and B.R. Roberts. 1983. Organic Spills Exposure Assessment Methodology. Prepared for the U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA, by Anderson-Nichols & Co., Inc. Palo Alto, CA.

Calabrese, A., J.R. MacInnes, D.A. Nelson, R.A. Greig and P.P. Yevich. 1984. Effects of long-term exposure to silver or copper on growth, bioaccumulation and histopathology in the blue mussel Mytilus edulis. Mar. Env. Res. 11:253-274.

Calambokidis, J., J. Mowrer, M.W. Beug and S.G. Herman. 1979. Selective retention of polychlorinated biphenyl components in the mussel, Mytilus edulis. Arch. Environ Contam. Toxicol. 8:299-308.

Campbell, A. 1983. Growth of tagged American lobsters, Homarus americanus, in the Bay of Fundy. Can. J. of Fish. and Aquatic Sci. 40:10:1667-1675.

Capuzzo, J.M. Crustacean Bioenergetics: The Role of Environmental Variables and Dietary Levels of Macronutrients on Energetic Efficiencies. Pater presented at 2nd International Conference on Aquaculture Nutrition, October 27-29, 1981, Rehoboth Beach, DE. Supported by NOAA, Office of Sea Grant under Grant Nos. 04-7-158-44104, 04-8-M01-149, and NA78AA-D-00102.

Carriker, M.R. 1961. Interrelation of functional morphology, behavior, and autecology in early stages of the bivalve Mercenaria mercenaria. J. of the Elisha Mitchell Sci. Soc. Vol. 77, No. 2.

Chambers, M.R. and H. Milne. 1975. Life cycle and production of Nereis diversicolor O. F. Muller in the Ythan Estuary, Scotland. Est. and Coastl. Mar. Sci. 3:133-144.

Cole, G.H., R.L. Copp and D.C. Cooper. 1977. Estimation of lobster population size at Millstone Point, Connecticut, by mark-recapture techniques, Proc. Nat. Shellfish Assoc. 1975-1976.

Connolly, J.P. and R. Tonelli. 1984. Modeling kepone in the striped bass food chain of the James River Estuary. Submitted to Estuarine, Coastal and Shelf Science.

DeLorenzo, D. 1983. New Bedford Biota Sampling Trip Report. Report from GCA to U.S. EPA.

Dexter, R.N. and S.P. Pavlou. 1978. Distribution of stable organic molecules in the marine environment: Physical chemical aspects. Chlorinated hydrocarbons. Marine Chemistry. 7:67-84.

DiToro, D.M. and L.M. Horzempa. 1982. Reversible and resistant components of PCB adsorption-desorption: Isotherms. Environ. Sci. Technol. 16:594-602.

DiToro, D.M., L.M. Horzempa, M.M. Casey and W. Richardson. 1982. Reversible and resistant components of PCB adsorption-desorption: Adsorbent concentration effects. J. Great Lakes Res. 8(2):336-349.

Driscoll, E.G. 1975. Sediment-animal-water interaction, Buzzards Bay, Massachusetts. J. Mar. Res. 33(3):275-302.

Duinker, J.C., M.T.J. Hillebrand and J.P. Boon. 1983. Organochlorines in benthic invertebrates and sediments form the Dutch Wadden Sea. Identification of individual PCB components. Netherlands J. of Sea Research 17:19-38.

Duinker, J.C., M.T.J. Hillebrand, K.H. Palmork and S. Wilhelmsen. 1980. An evaluation of the existing methods for quantitation of polychlorinated biphenyls in environmental samples and suggestions for an improved method based on measurement of individual components. Bull. Environ. Contam. Toxicol. 25:956-964.

Duinker, J.C., M.T.J. Hillebrand. 1983. Characterization of PCB components in Clophen formulations by capillary GC/MS and GC-ECD techniques. Environ. Sci. Technol. 17:449-456.

Ecker, R.M. and H.M. Degraca. 1974. Sediment Transport Coast of Northern California. ASCE National Meeting on Water Resources Engineering, January 21-25, Los Angeles, CA.

Elston, R., E.A. Crecelius, Y. Onishi and D.S. Trent. 1983. A Study of the Present and Alternative Sewage Outfall Location for Sequim, Washington - Phase 1. Prepared by Battelle Pacific Northwest Laboratories for the Washington State Dept. of Ecology, Olympia, WA.

EPA, Environmental Response Team and the Technical Assistance Team. 1983. Aerovox PCB Disposal Site Acushnet River and New Bedford Harbor, MA. (Tidal Cycle and PCB Mass Transport Study - January 10-12, 1983.). Final Report - March 4, 1983.

Epifanio, C.E. 1979. Growth in bivalve molluscs: Nutritional effects of two or more species of algae in diets fed to the American oyster Crassostrea virginica (Gmelin) and the hard clam Mercenaria mercenaria (L.). Aquaculture 18:1-12.

Eyler, L.L., D.S. Trent and M.J. Budden. 1983. TEMPEST--A Three-Dimensional Time-Dependent Computer Program for Hydrothermal Analysis. Volume II: Assessment and Verification Results. PNL-4348 Vol. II, Pacific Northwest Laboratory, Richland, Washington.

Field, D.E. 1976. CHNSED--Simulation of Sediment and Trace Contaminant Transport with Sediment/Contaminant Interaction. ORNL/NSFEATC-19, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Fletcher, G.L. and M.J. King. 1978. Seasonal dynamics of Cu^{+2}, Zn^{+2}, Ca^{+2} and Mg^{+2} in gonads and liver of winter flounder (Pseudopleuronectes americanus): evidence for summer storage of Zn^{+2} for winter gonad development in females. Can. J. Zool. 56:284-290.

Fowler, S.W., G.G. Polikarpov, D.L. Elder, P. Parsi and J.-P. Villeneuve. 1978. Polychlorinated biphenyls: Accumulation from contaminated sediments and water by the polychaete Nereis diversicolor. Mar. Biol. 48:303-309.

Galtsoff, P.S. 1937. Hatching and rearing of larvae of the American lobster Homarus americanus. pp. 233-236 In: Culture Methods for Invertebrate Animals, Ed. by F.E. Lutz, P.L. Welch, P.S. Galtsoff and J.G. Needham. Dover Publ., NY.

Geyer, H., P. Sheehan, D. Kotzias, D. Freitag and F. Korte. 1982. Prediction of ecotoxicological behaviour of chemicals: Relationship between physico-chemical properties and bioaccumulation of organic chemicals in the mussel Mytilis edulis. Chemosphere 11(11):1121-1134.

Goerke, H. and W. Ernst. 1977. Fate of ^{14}C-labelled DI-, Tri- and pentachlorobiphenyl in the marine annelid Nereis virens. Chemosphere 9:551-558.

Grant, W.D. and S.M. Glenn. 1982. Continental Shelf Bottom Boundary Layer Model; Volume II: Model/Data Comparison. Technical Report, Department of Ocean Engineering, Woods Hole Oceanographic Institution, pp. 62.

Haque, R., D.W. Schmedding and V.H. Freed. 1974. Aqueous solubility, adsorption, and vapor behavior of polychlorinated biphenyl Aroclor 1254. Env. Sci. and Techn. 8:2. p. 139.

Hoff, J.G. and R.M. Ibara. 1977. Factors affecting seasonal abundance, composition and diversity of fishes in a southeastern New England estuary. Estuar. Cstl. Mar. Sci. 5:665-678.

Hoffman, F.O., D.L. Schaeffer, C.W. Miller and C.T. Garten, Jr. 1978. Proceedings of a Workshop on: The Evaluation of Models Used for the Environmental Assessment of Radionuclide Releases. Gatlinburg, TN.

Howe, A.B. and P.G. Coates. 1975. Winter flounder movements, growth and mortality off Massachusetts. Trans. Amer. Fish. Soc. 104:13-29.

Huebner and R.W. Langton. 1982. Rate of gastric evacuation of winter flounder, Pseudopleuronectes americanus. Can. J. of Fish. and Aquatic Sci. 39(2):356-360.

Hunt, C.D. and D.L. Smith. 1983. Remobilization of metals from polluted marine sediments. Can. J. of Fish. and Aquatic Sci. 40(2):132-142.

Hunt, G., B. Myatt, D. Delorenzo, and J. Hall. June, 1983. New Bedford Environmental Investigation--Sampling and Analysis of Municipal Sewerage Lines and Bottom Sediments in the Vicinity of Sewerage Overflows for Polychlorinated Biphenyls (PCBs). Prepared for the U.S. EPA, RTP, NC 27111 (GCA-TR-83-42-G(3) by GCA Corporation, GCA/Technology Division, Bedford, MA.

HydroQual, Inc. February, 1981. Mathematical Modeling Estimate of Environmental Exposure Due to PCB Contaminated Harbor Sediments of Waukegan Harbor and North Ditch, for U.S. EPA, Region V.

HydroQual, Inc. September, 1981. Technical Addenda to Environmental Impact Statement for Proposed Waukegan Harbor Dredging Project, for WAPORA and U.S. EPA, Region V.

Hydroscience, Inc. April. 1978. Estimation of PCB Reduction by Remedial Action on the Hudson River Ecosystem, for New York State Department of Environmental Conservation.

Hydroscience, Inc. October, 1979. Analysis of the Fate of PCBs in the Ecosystem of the Hudson Estuary, for New York State Department of Environmental Conservation.

Karickhoff, S.W., D.S. Brown and T.A. Scott. 1978. Sorption of hydrophobic pollutants on natural sediments. Water Res. 13:241-248.

Klein-MacPhee, G. 1978. Synopsis of Biological Data for the Winter Flounder, Pseudopleuronectes americanus (Walbaum). NOAA Technical Report NMFS Circular 414 (FAO) Fisheries Synopsis No. 117. U.S. Dept. of Commerce/NOAA/NMFS.

Krone, R.B. 1962. Flume Studies of the Transport of Sediment in Estuarial Shoaling Processes. Hydraulic Engineering Laboratory and Sanitary Engineering Research Laboratory, University of California at Berkeley.

Lee, M.C., E.S.K. Chian and R.A. Griffin. 1979. Solubility of polychlorinated biphenyls and capacitor fluid in water. Water Research. 13:1249-1258.

Leo, A., C. Hansch and D. Elkins. December, 1971. Partition coefficients and their uses. Chemical Reviews 71(6):525-616.

Liang, S.S. and H. Wang. 1973. Sediment Transport in Random Waves. Technical Report No. 26, University of Delaware, College of Marine Studies.

Logan, D.T. and C.E. Epifanio. 1978. A laboratory energy balance for the larvae and juveniles of the American lobster Homarus americanus. Marine Biology 47:381-389.

Lombardo, M.I. and L.L. Eyler. 1982. Three-Dimensional Near Field Analysis of the N Reactor Thermal Discharge. FATE-82-111 Informal Report, Pacific Northwest Laboratory, Richland, WA.

Luoma, S.N. 1982. A statistical study of environment factors controlling concentrations of heavy metals in the burrowing bivalve Scrobicularia plana and the polychaete Nereis diversicolor. Estuarine, Coastl. and Shelf Sci. 15:95-108.

Luoma, S.N. 1981. A statistical assessment of the form of trace metals in oxidized estuarine sediments employing chemical extractants. The Science of the Total Env. 17:165-196.

MacDonald, J.S. 1983. Laboratory observations of feeding behaviour of the ocean pout (Macrozoarces americanus) and winter flounder (Pseudopleuronectes americanus) with reference to niche overlap of natural populations. Can. J. of Zool. 61(3):539-546.

Mackay, D., A. Bobra, W.Y. Shiu and S.H. Yalkowsky. 1980a. Relationships between aqueous solubility and octanol-water partition coefficients. Chemosphere 9:701-711.

Mackay, D., R. Mascarenhas, W.Y. Shiu, S.C. Valvani and S.H. Yalkowsky. 1980b. Aqueous solubility of polychlorinated biphenyls. Chemosphere. 9:257-264.

Mauchline, J. 1977. Growth of shrimps, crabs and lobsters - an assessment. J. Cons. int. Explor. Mer. 37(2):162-169.

McCall, P.L. 1973. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. J. of Mar. Res. 35(2)221.

McLeese, D.W., C.D. Metcalfe and D.S. Pezzack. 1980. Uptake of PCBs from sediment by Nereis virens and Crangon septemspinosa. Environ. Contam. Toxicol. 9:507-518.

McLeese, D.W., C.D. Metcalfe and D.S. Pezzack. 1980. Bioaccumulation of chlorobiphenyls and endrin from food by lobsters (Homarus americanus). Bull. Environm. Contam. Toxicol. 25:161-168.

Metcalf & Eddy/Engineers. 1983. Acushnet Estuary PCBs Data Management Final Report. Prepared for the U.S. Environmental Protection Agency, Region I, Office of Program Support Under Contract No. 68-04-1009.

Morrissey, T.D. 1971. Movements of tagged American lobsters, Homarus americanus liberated off Cape Cod, Massachusetts. Trans. Amer. Fish. Soc. 1:117-120.

Neuhoff, H.-G. 1979. Influence of temperature and salinity on food conversion and growth of different Nereis species (Polychaeta, Annelida). Marine Ecology - Progress Series 1:255-262.

Onishi, Y. 1981. Sediment-Contaminant Transport Model. Journal of Hydraulics Division, ASCE, Vol. 107, No. HY9, Proceedings No. 16505, pp. 1089-1107.

Onishi, Y., D.L. Schreiber and R.B. Codell. 1980. Mathematical Simulation of Sediment and Radionuclide Transport in the Clinch River, Tennessee. Contaminants and Sediments, Ed. by R.A. Baker, pp. 393-406, Vol. 1, Ch. 18, Ann Arbor Science Publishers, Inc., Ann Arbor Science Publishers, Inc., Ann Arbor, Mississippi.

Onishi, Y., R.J. Serne, E.M. Arnold, C.E. Cowan and F.L. Thompson. 1981. Critical Review: Radionuclide Transport, Sediment Transport, and Water Quality Mathematical Modeling; and Radionuclide Adsorption/Desorption Mechanisms. NUREG/CR-1322 (PNL-2901). NUREG/CR-1322 (PNL-2901), U.S. Nucelar Regulatory Commission, Washington, D.C.

Onishi, Y. and D.S. Trent. 1982. Mathematical Simulation of Sediment and Radionuclide Transport in Estuaries -- Testing of Three-Dimensional Radionuclide Transport Modeling for the Hudson River Estuary, New York. NUREG/CR-2423 (PNL-4109), U.S. Nuclear Regulatory Commission, Washington, D.C.

Onishi, Y., G. Whelan and R.L. Skaggs. 1982. Development of a Multimedia Radionuclide Exposure Assessment Methodology for Low-Level Waste Management. PNL-3370, Pacific Northwest Laboratory, Richland, WA.

Onishi, Y., D.W. Mayer and R.S. Argo. 1982. Sediment and Toxic Contaminant Transport Model in Coastal Waters. In: Finite Element Flow Analysis, Ed. by T. Kawai, pp. 733-740. University of Tokyo Press, Tokyo, Japan.

Oviatt, C.A. and S.W. Nixon. 1973. The demersal fish of Narragansett Bay: An analysis of community structure distribution and abundance. Estuar. Cstl. Mar. Sci. 1:361-378.

Partheniades, E. 1962. A Study of Erosion and Deposition of Cohesive Soils in Salt Water, Ph.D. Thesis, University of California at Berkeley.

Patrick, W.H., R.P. Gambrell and R.A. Khalid. 1977. Physicochemical factors regulating solubility and bioavailability of toxic heavy metals in contaminated dredged sediment. J. Environ. Sci. Health, A12(9):475-492.

Payne, K. and W.F. Pickering. 1975. Influence of clay-solute interactions on aqueous copper ion levels. Water, Air, and Soil Poll. 5:63-69.

Pierce, D.E. and A.B. Howe. 1977. A further study on winter flounder group identification off Massachusetts. Trans. Amer. Fish. Soc. 106:131-139.

Rhoads, D.C. 1967. Biogenic reworking of intertidal and subtidal sediments in Barnstable Harbor and Buzzards Bay, Massachusetts. J. Geol. 75:461-467.

Rhoads, D.C. 1970. The influence of deposit feeding organisms on sediment stability and community trophic structure. J. Mar. Res. 28:150-178.

Rubinstein, N.I., E. Lores and N.R. Gregory. 1983. Accumulation of PCBs, mercury and cadmium by Neris virens, Mercenaria mercenaria and Palaemonetes pugio from contaminated harbor sediments. Aquatic Toxicology 3:249-260.

Sanders, H.L. 1958. Benthic studies in Buzzards Bay. I. Animal-sediment relationship. Limnology and Oceanography. III(3):245.

Sanders, H.L. 1960. Benthic studies in Buzzards Bay. III. The structure of the soft-bottom community. Limnol. Oceanog. 5:138-152.

Sayler, G.S., R. Thomas and R.R. Colwell. 1978. Polychlorinated biphenyl (PCB) degrading bacteria and PCB in estuarine and marine environments. Estuarine and Coastal Marine Science 6:533-567.

Schmidt, R.L. 1978. Copper in the marine environment. Part I. CRC Critical Reviews in Environmental Control. 8(2):101-152.

Schmidt, R.L. 1978. Copper in the marine environment. Part II. CRC Critical Reviews in Environmental Control. 8(3):247-291.

Summerhayes, C.P., J.P. Ellis, P. Stoffers, S.R. Briggs and M.G. Fitzgerald. 1977. Fine-Grained Sediment and Industrial Waste Distribution and Dispersal in New Bedford Harbor and Western Buzzards Bay, Massachusetts. W.H.O.I.-76-115. Sea Grant Program (Technical Report prepared for the Department of Commerce, NOAA, Office of Sea Grant under Contracts 04-6-158-44016 and 04-6-158-44106.

Tenore, K.R., J.C. Goldman and J.P. Clarner. 1973. The food chain dynamics of the oyster, clam, and mussel in an aquaculture food chain. J. exp. mar. Biol. Ecol. 12:157-165.

Tenore, K.R. and W.M. Dunstan. 1973. Comparison of feeding and biodeposition of three bivalves at different food levels. Marine Biology 21:190-195.

Thomann, R.V. 1981. Equilibrium model of fate of microcontaminants in diverse aquatic food chains. Can. Journal of Fisheries and Aquatic Sciences 38(3):280-296.

Thomann, R.V. and J.P. Connolly. 1984. Model of PCB in the Lake Michigan lake trout food chain. Environ. Sci. Technol. 18(2):65-71.

Thomann, R.V. and J.P. St. John. 1979. The fate of PCBs in the Hudson River ecosystem, In: Health Effects of Halogenated Aromatic Hydrocarbons. Ann. New York Acad. Sci. 320:610-629.

Trent, D.S., L.L. Eyler and M.J. Budden. 1983. TEMPEST--A Three-Dimensional Time-Dependent Computer Program for Hydrothermal Analysis. Volume II. Assessment and Verification Results. PNL-4348 Vol. I, Pacific Northwest Laboratory, Richland, Washington.

Tulp, M.Th.M. and O. Hutzinger. 1978. Some thoughts on aqueous solubilities and partition coefficients of PCB, and the mathematical correlation between bioaccumulation and physico-chemical properties. Chemosphere 7(10):849-860.

Tyler, A.V. and R.S. Dunn. 1976. Ration, growth, and measures os somatic and organ coindition in relation of meal frequency in winter flounder, Pseudopleuronectes americanus, with hypotheses regarding population homeostasis. J. Fish. Res. Board Can. 33:63-75.

VanGuelpin, L. and C.C. Davis. 1979. Seasonal movements of the winter flounder, Pseudopleuronectes americanus, in two contrasting inshore locations in Newfoundland. Trans. Amer. Fish. Soc. 108:26-37.

Windom, H.L., K.T. Tenore and D.L. Rice. 1982. Metal accumulation by the polychaete Capitella capitata: influences of metal content and nutritional quality of detritus. Canadian J. of Fish. and Aquatic Sci. 39:(1):191-196.

Zell, M. and K. Ballschmitter. 1980. Baseline studies of global pollution. III. Trace analysis of PCB by ECD glass capillary gas chromatography in environmental samples of different trophic levels. Fresnius Z. Anal. Chem. 304:337-349.

Zirino, A. and S. Yamamoto. 1972. A pH-dependent model for the chemical speciation of copper, zinc, cadmium, and lead in seawater. Limnology and Oceanography. 17:(5):661-671.